ENGINEERING

…issue

…TURES TO
…STAND EARTHQUAKES

…Review
…FLUX

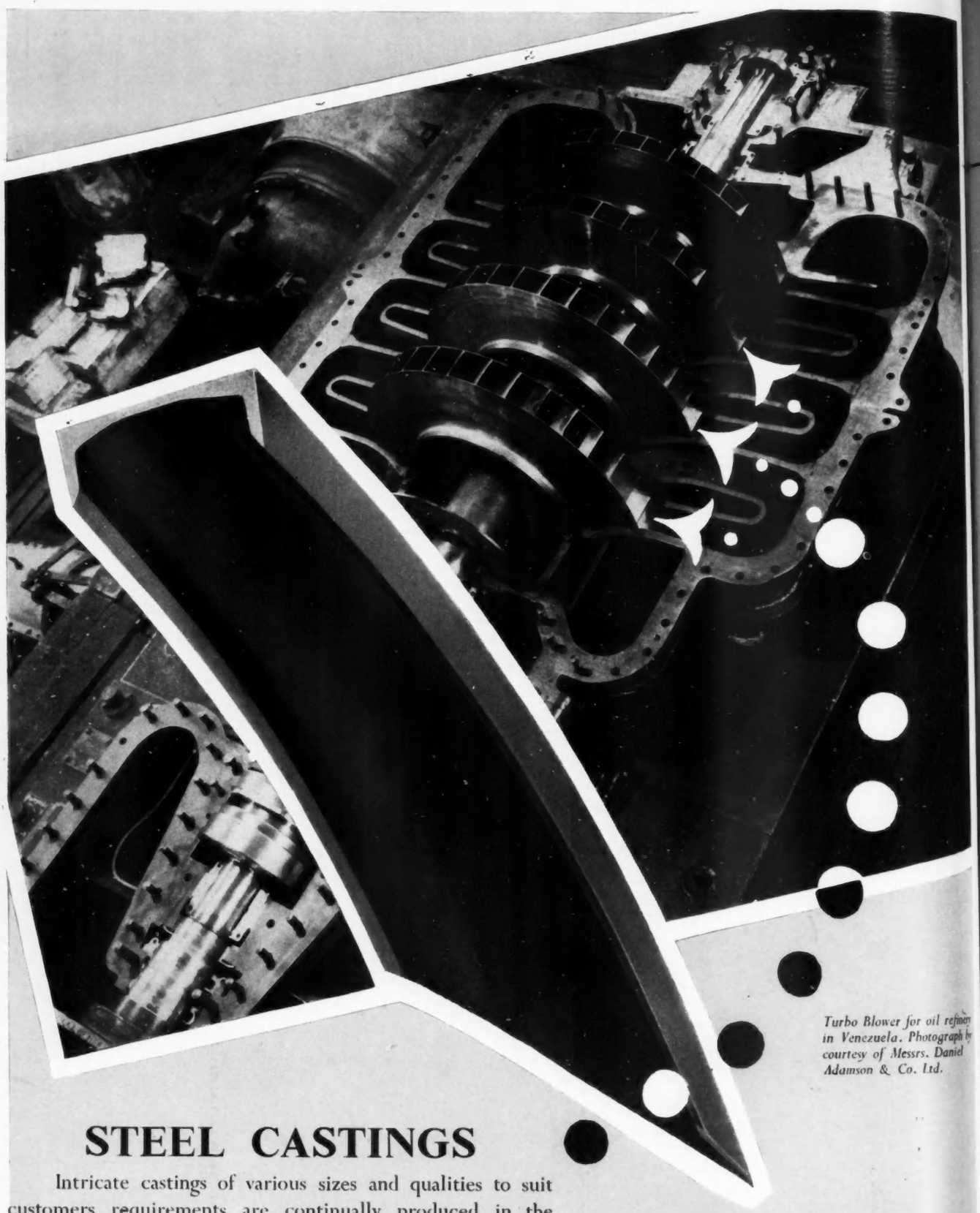
… JOURNEY

…ies in the Commonwealth
…WRIGHTSON & CO. LTD.

… LOADS SUPPLIED
… ONE COMPRESSOR

…hibitions
…RICAL PLANT
…VENDING MACHINES

…g a Ventilator Cowl



Turbo Blower for oil refinery in Venezuela. Photograph by courtesy of Messrs. Daniel Adamson & Co. Ltd.

STEEL CASTINGS

Intricate castings of various sizes and qualities to suit customers requirements are continually produced in the Hadfields foundry.

Special supervision coupled with distinctive workmanship and technical dexterity are embodied in the manufacture of Hadfields castings, produced in carbon low alloy, manganese and other wear resisting steels, stainless and heat resisting steels.

HADFIELDS
SHEFFIELD

HADFIELDS LTD., EAST HECLA WORKS, SHEFFIELD, ENGLAND

ENGINEERING

Vol. 187 No. 4853 13 March 1959 PUBLISHED EVERY FRIDAY

Contents

321 **Leading Article**
Volunteers

322 **Plain Words**

323 **Letters to the Editor**
Mechanics of the Universe
Safety Belts in Cars

328 **Companies in the News**

329 **Automobile Engineering**
Cars for an International Market: Geneva 1959

330 **In Parliament**

332 **Special Article**
Lunar Journey

334 **Atomic Review**
Fast Flux

342 **Book Reviews**
Technical Drawing
Telecommunications Economics
Gas Turbines for Aircraft

342 **New Books**

343 **On the Shelf**

344 **Meetings and Papers**

352 **Engineering at Home**
Heat Pumps for the Home
Central Heating Circulator

. . . . . .

Management

322 Weekly Survey
337 Companies in the Commonwealth: 6—Head, Wrightson and Company Limited

324 **Plant and Equipment**
High Precision Grinder
Component Recording
Bending Calculator
Vending Machine Exhibition
Electrical Engineers' Exhibition

331 **The Human Element**

338 **Design**
Skip Winding Plant at Rufford Colliery
Bearings with Races Made of Wire
Ball-Bearing Slewing Rings
Three New British Standards
Split Cotter-Pins
Plastics Scales
Refrigerated Display Cabinets

341 **Research and Development**
Mixed Loads Supplied from One Compressor: Mach-One Valve Simplifies Pneumatic Conveyor Systems
Isaac Newton Telescope: Parallax Work at the Cassegrain Focus

345 **Metals and Materials**
Large Injection Mouldings in Polystyrene
Printing and Drawing Paper
Sintered High Density Metal
PTFE Insulated Instrument Wire
Piezoelectrics

346 **Construction**
Structures to Withstand Earthquakes

349 **Operation and Maintenance**
Free-Piston Engines Afloat
Atmospheric Pollution by Solid Particles

352 **Production**
Measuring Surface Finish
Automation in Tyre Manufacture

Volunteers

A MAN will do all sorts of unpleasant jobs for himself which he would not dream of doing for his employer. If necessary, he will clear a blocked drain, or get soaking wet while doing urgent work in the garden. But if he were formally asked at the office to do any of these things he would take it as an insult. Yet there are certain kinds of work which a man will do voluntarily—things outside the normal range of duties—which would not be done at all if they were not done voluntarily.

The British Standards Institution is aided by some 3,000 committees, on which 17,000 people serve. There is no special glory to be acquired by serving on these committees, and although their meetings are mostly held during office hours the individual members inevitably become committed to extra time and thought outside the normal run of work. The organisations who allow their staff to attend these committee meetings are likely to benefit in the long run, if only because their interests are represented on a policy-forming body, but others take a narrower view and restrict the extent of such outside commitments. The BSI would not have gone very far if everyone had adopted that attitude.

The professional institutions derive considerable benefit from voluntary work. In addition to the councils, there are numerous committees and subcommittees, in London and in the branches, which work quietly but effectively and in many ways help the engineering profession and industries. Indeed the vigour of an institution is in direct proportion to the amount of work which members put into it voluntarily. The secretariat must inevitably do the full-time work but they are impotent if there is not a group of members who are capable of giving expression to the wishes and aspirations of the membership as a whole. For the president, his year of office, if he takes it seriously and can spare the time, is an extremely arduous period, involving much travel and constant attention. The presidency is no sinecure.

The City and Guilds of London Institute have decided to award honorary membership to individuals and organisations who have given freely of their time and resources, so much importance do they attach to voluntary work. The institute is best known for its system of examinations in technical subjects, though in the past it also founded several colleges, including the City and Guilds College, which is the engineering section of the Imperial College of Science and Technology. In its examination and syllabus activities it depends on various classes of members—corporate and individual—who contribute time and money. In the institute's own words: " membership secures no material benefit which is not available to any other individual or organisation interested in, or dependent upon, the work of the institute. On the contrary it increases the liability of members to give yet more of their time and resources to institute affairs, such as senior committee work, including service on Council. The institute, on the other hand, stands to gain much from the fact that example is contagious, and also from being able to consult persons of wide and varied experience in all branches of industry and commerce. Membership, therefore, signifies a real belief in technical education, and in the work of the institute in particular; it means active service and giving rather than receiving, and it is a worthy way of recognising the debt owed to the ancient guilds for founding and maintaining the institute for three-quarters of a century."

A group of men in the building industry have made time to serve a committee which is aiming to raise at least £25,000 for the National Council of Social Service. The money will be used to support one of the Council's many spheres of interest, namely, the social needs of young people. The committee believe that the development of creative interests is fundamental to education and the most likely means of ensuring that leisure is used constructively. They aim to raise a substantial sum for buildings and equipment.

Sometimes it is easier for a man to give money rather than time. He can send a contribution or sign a seven-year deed of covenant quite easily if he is so minded. The benevolent funds of the professional institutions depend on members' thoughtfulness, but it is only a minority of members who take the trouble. Giving a donation to a charity is a lone act of service, whereas serving on a committee is a gregarious habit. As children, at home and at school, our goings and comings were strictly controlled, and it was the same during the years of training. For many of us, it is not until our thirties or forties that we gain our freedom—the freedom to rove which committees give us. Apart from the contribution we ourselves make, committees contribute something to our own experience, carrying us from the confined twin worlds of home and office into a constellation of new and unfamiliar situations. Committees liberate us, making us wanderers once again.

Cover Picture.—*Hand riveting a sheet metal upstand for a ventilator cowl. A well balanced ventilation system not only serves to maintain a good working atmosphere but provides a safety valve in the event of a fire.*

(*Nurnberg photograph for* ENGINEERING)

Plain Words

Many people must have been surprised to learn from a recent article in *The Times* that music is the greatest passion among Harwell scientists. There are at Harwell, it was noted, a large number of chamber groups and choirs which flourish in a quite unofficial way. I have not the least doubt that the interests and tastes of the predominantly scientific society of Harwell are as catholic as anywhere in the country.

The suggestion that lectures on art, music, economics and current affairs should be injected into an already overfull engineering syllabus has always caused my hackles to rise. It's not the suggestion itself that ires me—far from it—but the implication that engineers and scientists are narrower in outlook than others. The complementary suggestion that arts people should do some science is put forward so much less frequently that the issue is left weighing against the engineer—and that is an injustice.

For some years after the war I was meetings secretary of an association which met monthly for dinner followed by an informal address from a speaker knowledgeable in a topic of general or current interest. Membership of the association was well distributed among graduates of most faculties—law, arts, medicine, economics, as well as science and engineering and not a few from divinity—though the engineers and medicos predominated. Topics of discussion included subjects of a general scientific-cum-technical character, but I well remember a talk on the history of the ballet, a 'cellist who brought along her instrument and illustrated her comments by playing, and one Bacchanalian occasion when the subject was home-made wines and the speaker handed around a generous array of well-filled bottles.

While admitting that I never checked back through the attendance book, I will hazard a guess that it was the engineers and scientists who supported the meetings whatever the subject, whereas the arts people would only come along if the topic was within their experience. All too often when a near-technical subject was on the programme the arts people excused their absence with the plea that they would " not have understood what it was all about."

Of course engineers are better for knowing something outside their professional field. What disturbs me is that so many well-intentioned educationalists presume that engineers are more in need of this " broadening " than other groups. I'd like to bet that outside the ranks of professional musicians the most sensitive players are engineers, physicists or mathematicians. So just leave us alone. You can put me down as a little prairie flower; anyone who tries to cultivate me does so at his peril.

CAPRICORN

Weekly Survey

Water Power for North Scotland

The North of Scotland Hydro-Electric Board announced last week that it had placed the main civil engineering contracts for the construction of the Strathfarrar and Kilmorach Scheme. The published cost of the scheme was £14 million and the capacity to be installed in the four stations at Kilmorach, Aigas, Culligran and Deanie is 102 MW, representing 60 per cent of the hydro-electric schemes at the constructional stage at the end of 1958.

The Mitchell Construction Company has been awarded the contracts for two dams on Loch Monar, which will supply the Deanie power station; for the Deanie tunnel; and the Culligran tunnel and power station. Duncan Logan (Contractors) Limited, Dingwall, will construct the Beannachran dam supplying the Culligran station, and the Misgeach Aqueduct, while A. A. Stuart and Sons (Glasgow) Limited will construct the Aigas and Kilmorach dams and power stations. A 132 kV transmission line will be erected by Riley and Neate Limited to carry the output of the power stations to the Highland Grid near Beauly.

The annual report shows that at the end of 1958, schemes already in operation had a combined capacity of 813,066 kW, while those at the constructional stage (including Strathfarrar and Kilmorach) totalled 169,256 kW. In addition schemes totalling 448,000 kW were in course of promotion, while schemes totalling a further 224,000 kW were under survey. The schemes in course of promotion comprise the Awe scheme together with the Cruachan pumped-storage project with 400,000 kW of combined pumping and generating plant. The amended scheme has been referred to the Secretary of State for Scotland for confirmation preparatory to being laid before Parliament, and it is hoped the scheme will be completed by 1965-66, by which time the South of Scotland Electricity Board hope to have sufficient surplus high merit generating plant at nights and week-ends to supply the essential low-cost pumping units.

Of the schemes under survey the most important is that for Upper Findhorn-Monadhliath-Loch Ness, which will comprise 150,000 kW or two-thirds of the total under this heading.

Car Assembly in South Africa

The recent announcement by the South African Government that there is to be a further investigation into the South African motor assembly industry is a further example of the strained relations which have existed for some time between the Government and the motor industry. During the past year the Minister of Economic Affairs blamed the industry as being one of the principal causes of the serious fall in the country's foreign exchange reserves and two previous investigations were made at the instigation of the Government, in 1955 and 1957 respectively. At each of these the industry has succeeded in justifying the higher price of cars assembled locally from British or United States components as compared with the price of corresponding cars elsewhere. Nevertheless, when in the last Budget extra duties were imposed, the Finance Minister announced that he would discuss with the Minister of Economic Affairs whether the industry could absorb the additional duties without passing them on to the public. Later, however, assemblers and traders were permitted to pass on the duties.

It is reported that the main emphasis in the new investigation will be on the possibility of manufacturing complete motor vehicles, or at least a much wider range of components, in South Africa and thus building up a motor industry which could supply the home market at reduced prices and also start to export. There is probably a good deal of truth in the argument that one of the main reasons for high prices lies in the very wide range of cars offered in a relatively small market. Moreover, the number of models to be assembled in South Africa is increasing steadily: in November last, Renault and Citroën announced that they had completed arrangements for local assembly, while the German Borgward and Italian Moretti companies are investigating the possibility of local assembly or manufacture. The former is believed to be considering the production of a small car primarily for the native market.

The result of the Government investigation may clearly have important repercussions on car manufacturers exporting to the Union. It would appear almost certain, however, that local manufacture on an appreciable scale would involve a very considerable curtailment in the choice available to the South African public.

Invest in Australia

The Australian Finance and Commerce Newsletter for February 1959 draws attention to the growth in Australia's exports to South East Asia. This applies particularly to the heavy engineering and metal industries in which there would appear to be good prospects for further profitable investment of British capital, in addition to the substantial amounts already invested.

Australian exporters have undertaken a number of trade drives in Asia, a recent example being the chartering of a special ship which visited ports in many Asian countries, carrying a floating exhibition of Australian manufactured products. Deliveries of engineering products, particularly tractors, pumps, earthmoving equipment and agricultural machinery, under the Colombo Plan have also helped to make Australian manufacturers better known in Asian countries. Japan and India are at present the principal markets, the former taking metals and metal manufactures to the value of £A8·6 million in 1956-57, while the latter took metals, metal manufactures and machinery valued at £A6·9 million. Indonesia purchased these products to the value of £A2·2 million, Singapore to the value of £A1·5 million and Malaya to the value of £A1·0 million.

In the financial year 1956-57 the inflow of private investment to Australia from the United Kingdom was £A58·4 million, compared with £A66·8 million in the previous year. The Australian Minister for Trade has estimated that total new capital investment in Australian manufacturing industries by both local and overseas investors now amounts to more than £200 million per annum.

It is, of course, easy to overrate the advantage of proximity to markets, which may be more than offset by higher costs of production in Australia than in the United Kingdom. Nevertheless, the growing Australian trade with South East Asia must steadily increase the range of engineering products which can be economically produced in Australia.

A Worthy Pioneeer

The United States Army placed an instrumented probe within 37,000 miles of the moon. The 13·4 lb payload, " Pioneer IV ", of a Juno II rocket passed by the moon at 22.24 GMT on 4 March, some 41 hours after it had been launched from Cape Canaveral. Radiation detectors and a photoelectric sensor were carried.

The journey to the moon took longer than was intended, apparently due to a small error in the angle of the initial flight path. As a result, the probe did not approach close enough for the

photoelectric device—an experimental forerunner of a form of television—to receive enough moonlight to operate. It has also been reported that no new radiation belts were recorded, but the distance from the moon was too great for the possibility of a zone of radiation trapped in a lunar magnetic field to be ruled out. Now the probe is turning into a solar orbit, having been tracked by the Goldstone tracking station in California to a distance of 406,020 miles. At this point the batteries became exhausted. The instruments were contained in a glass-fibre cone, gold plated to make it suitable as a telemetry aerial.

Although aiming their rocket for impact on the moon, the firing crew expected at best to come within 15,000 miles of their target. Thus the Russian moon rocket launched in January was a considerably more accurate device (passing within 5,000 miles of the moon) and it seems likely that its last stage was guided, in contrast to the final stage of the Juno II, which was only spin-stabilised. This fact, coupled with the difference in weight carried by the two probes—about 600 lb—suggests that the Soviet Union will keep her lead in astronautics. For whereas the present experiment seems to be at about the limit of the Juno's capabilities, it is likely that refinement of the velocity control of the Russian rocket will enable it to hit or encircle the moon in the near future. The capabilities of the US Atlas as a vehicle for lunar probes remain to be seen. In one respect however, the United States has a clear lead in extra-terrestrial research: its results are published. The facts we have concerning the newly-discovered radiation belts above the earth come from American, not Russian, sources. Indeed, as Professor A. B. Lovell has suggested, the West has no published evidence that the Soviet lunar rocket even existed.

Spring Thaw on the Roads

Now that improvements to the road system have achieved much higher priority on the national capital expenditure list, the air is thick with prescriptions as to how the money should be spent and how a better road system can be organised.

The latest traffic returns issued by the Ministry of Transport show that there are nearly 8 million vehicles on the roads in this country. It is generally accepted that the figure will rise fairly steeply in the next decade. This has touched off a Fabian pamphlet called *What Shall We Do About the Roads?* by Mr. W. T. Rodgers. The pamphlet makes out a case for a National Highway Construction Board and a London Traffic Authority over both of which there would be a National Highway Authority. This attempt to solve the problem of road congestion and arrange the right priorities may not have universal appeal, but the pamphlet's insistence that there is danger of spending too high a proportion of public money on fast motorways to the disadvantage of more humdrum schemes in urban areas raises an issue on which there could well be further debate.

Meanwhile, the British Road Federation has issued the seventh of the series *See How They Go*, which is a schedule of estimated completion dates for road schemes between 1958 and 1963. It shows that over the next five years, the present programme reaches its peak of activity in the current year. The chart covers schemes costing over £100,000 in England and Wales started from July to December, 1958.

So far as parking is concerned, the Traders' Road Transport Association Limited, which represents the "C" Licence holders' interests, has launched its nation-wide scheme called "Kerb Space is Precious." The scheme was put into operation in London last October and as from the beginning of this month extended throughout England, Scotland and Wales. Finally, the Roads Campaign Council has issued the text of a talk given by Mr. Granville Berry, the city engineer and surveyor of Coventry, calling for an improvement in the standard of street lighting. It is pointed out that a better standard of road lighting will reduce accidents and increase the traffic capacity and average speed of vehicles on highways. The plea is also made for street lighting for motorways at the cost of a mere £4,000 a mile.

Educating Our Dependents

Recent events in Nyasaland lend topical interest to a publication by the Central Office of Information entitled *Higher Technical Education in UK Dependencies*, which summarises developments in this field since 1947. Before the war, efforts were directed primarily towards agricultural education since there was little demand for craftsmen trained in modern techniques, and clerical employment was more popular than craft or technical work. Since the war, however, trade and technical schools have been developed rapidly at the secondary level and technical institutes have been set up in many territories to provide more advanced evening and part-time courses for those already at work.

The question of providing centres of higher technical and vocational education was first given prominence in the 1947-49 report of the Inter-University Council for Higher Education in the Colonies which was set up to foster the development of higher colleges and their advance to university status. In West Africa it was decided to set up a new type of post-secondary institution known as a regional college, which was considered necessary owing to the speeding up of the Africanisation of the public services and the growing requirements for technically skilled men and women for development schemes.

In July, 1957, the Advisory Committee on Colonial Colleges of Arts, Science and Technology was reconstituted as the Council for Overseas Colleges of Arts, Science and Technology. It is responsible for advising on questions of professional, technical and commercial education at the technical college level, and has concerned itself mainly with the four colleges in Africa: Fourah Bay College, Sierra Leone; the Nigerian College of Arts, Science and Technology; the Royal Technical College of East Africa, Nairobi; and Kumasi College of Technology in Ghana; and the Singapore Polytechnic. It is also responsible for the Jamaica Institute of Technology which was opened last year. A Polytechnic Institute is now in course of establishment at Port of Spain, Trinidad.

Trade Union Shape and Size

What has been happening to trade-union membership in the past year? Some of the answers are provided by an article in a recent issue of the *Ministry of Labour Gazette*. First, how many unions are there? Apparently in Great Britain and Northern Ireland at the end of 1957 there were 653 trade unions. This represents a fall of two on the previous year, accounted for by the demise of seven small unions and the creation of two new ones. The total membership of all these unions was 9,752,000, an increase of 48,000 on the year before. The number of male workers rose by 56,000 to 7,876,000, while that of women fell by 8,000 to 1,876,000. So far as size of unions is concerned there are 17 in the top class (over 100,000) sharing 6½ million members between them. At the other end of the scale are the 134 unions with less than 100 members each. Size obviously counts for a great deal as nearly 91 per cent of all workers are in unions with at least 50,000 members.

One set of figures given in the same issue of the *Gazette* is of interest in a political as well as an industrial context. Union funds at the end of 1957 totalled £80,796,000. This is a rise of over £1 million on 1956 and over £30 million on 1947. All of which would seem to indicate that the trade unions are in good shape.

Letters to the Editor

MECHANICS OF THE UNIVERSE

Kapp's Theory

SIR, In the course of the leading article in ENGINEERING of 27 February, the interesting point is made that under the influence of centrifugal force a spinning star might conceivably divide into two equal parts, each of which might fly away out of the gravitational field of the other, leaving behind their common centre of mass and a few odd fragments. This would be one way of saving the theory that the planets are remnants of a companion star to the sun that broke under centrifugal force. It would account for the disappearance of the parent body. I should not dare to be dogmatic about any cosmological theory but should like to mention some considerations that seem to me to weigh rather heavily against this suggestion.

Firstly, there is a significant difference between a fly-wheel and a spinning star. With a fly-wheel, breakage occurs simply when centrifugal force exceeds the tensile strength of the material. But with a star, breakage occurs when (and only when) centrifugal force exceeds the sum of gravity and tensile stress of the material. If the material of which the star is composed has no tensile strength, no part of it can be thrown off by centrifugal force. This is why the theory is untenable that the planets condensed out of wisps of gas thrown off by a companion to the sun. If the tensile strength is low, pieces will break away at an angular velocity for which the excess of centrifugal force over gravity is small; the pieces will rise a small distance from the star and then fall back on to it. If the tensile strength is greater pieces will not break away until the excess of centrifugal force is considerable. The pieces may then not fall back on to the star but circle it as satellites. Pieces that broke away with sufficient initial velocity to escape from the gravitational field of the parent body would have to have enormous initial velocities and be thrown off with enormous force. We have recently been made familiar with the force per unit mass needed to propel a missile out of the earth's field, which has but a small fraction of the field intensity of a large star. For a star to hold together until centrifugal force reached so high a value it would have to be composed of a substance with a fantastically high tensile strength.

Secondly, one should expect sundry weak areas to occur not far below the surface of a star and breakage to occur at any of these as soon as centrifugal force became high enough.

Thirdly, there is the probability that centrifugal force exceeds gravity near the surface of a star when gravity exceeds centrifugal force further down in the interior. Let the mass of the star below a given point within the star at a distance r from the centre be m. The gravitational field strength at that point is $G\,m/r^2$ and the centrifugal force on unit mass is $\omega^2 r$. Let σ be the average mass density. Then $m = (4/3)\,\pi\,\sigma\,r^3$. From this it follows that $\omega^2 = (4/3)\,\pi\,G\,\sigma$ when centrifugal force balances gravity.

It is reasonable to assume that σ increases towards the centre of a star. So centrifugal force would be able to cause breakage of pieces of the star near the surface at an angular velocity at which the bulk of the star was held together by gravity.

It should also be pointed out that, if the half-life of matter is assumed to be infinite, no theory has yet been produced to explain why a spinning star can ever increase its angular velocity until centrifugal force exceeds gravity. For the increase in angular velocity is attributed to shrinkage, and this must cease when the two opposed forces are equal. But if the half-life of matter is finite, as I claim, extinctions within the star lead to a reduction in gravity, which must continue until it is less on unit mass than centrifugal force. Thus the continuous extinction of

Continuing

Letters to the Editor

matter theory explains why planets are cast off from a parent star without making it necessary to explain away the parent itself. This has dwindled to about one-thousandth of its original mass. As mentioned in your leading article I claim that it is the planet Jupiter.

Yours faithfully,
REGINALD O. KAPP.

12 Caxton Street,
London, SW1.
4 March, 1959.

SAFETY BELTS IN CARS

SIR, I have just read the note in your issue of 6 March (page 297) on the British Safety Council's report on safety belts in cars.

I believe it will be of interest to your readers to know that almost simultaneously with the publication of the report, the Council embarked on a new scheme for testing and approving equipment for all aspects of safety, and that the first equipment to undergo the Council's exhaustive tests were car seat belts and harnesses.

Three manufacturers of belts have so far been granted the Council's seal of approval. Some of the tests undergone included those relating to strength retention in water, under strong lights (simulating sunlight), the extent of tear, and a test of 15 *g* which is equivalent to a pull of up to 3,000 lb.

After the official report has been prepared and accepted as satisfactory, the manufacturer is given a certificate and copies of the seal. These may be used in advertising matter or upon any unit of any article, with the proviso that the seal and certificate applies only to the product tested and not to any other article, or to any variation of the products made by the manufacturer. The products are subject to periodic tests, in order to establish that the Council's high standards are constantly met.

The scheme helps to stop unscrupulous commercial exploitation, as was the case when motor cyclists' crash helmets, many of which were quite useless, were flooded on the market. The Council has thus safeguarded the interests of safety-belt users by offering to test any equipment submitted to them by manufacturers.

Yours faithfully,
CYNTHIA M. ARAKIE,
Information Officer.

British Safety Council,
60 Westbourne Grove, London, W2.
7 March, 1959.

PLANT ENGINEERS NEW STYLE

With the consent of the Board of Trade, the name of the Incorporated Plant Engineers, 2 Grosvenor Gardens, London, SW1, has been changed to the " Institution of Plant Engineers," with effect from 16 January last. The Institution is incorporated as a company limited by guarantee and, for some time, has held a Board of Trade licence to dispense with the word " Limited."

★ ★ ★

In the article (ENGNG., 23 Jan. '59, p. 101) describing the self-adjusting levels with the compensator unit developed jointly by Hilger and Watts Limited, and Cooke, Troughton and Simms Limited, both firms were stated to be members of the Vickers Group. Hilger and Watts, however, are not members of the group, but are an independent public company.

Plant and Equipment

HIGH PRECISION GRINDER

One of the machines demonstrated at the new showrooms and service centre that A. A. Jones and Shipman Limited have opened at 50/52 Great Peter Street, London, SW1, is the Fig. 1212 high precision cylindrical grinder which has a capacity of work up to 5 in diameter by 12 in long. Head and work table are shown in the accompanying illustration. Particular features are the large diameter (10 in) grinding wheel that can be accommodated, and the very fine wheel-feed control.

The controls are hand operated; the traverse has two speeds for coarse and fine movements, while the cross slide has a micrometer feed of 0·000,005 in (0·000,01 in on diameter). Both motions have adjustable dead stops; that on the cross feed can be adjusted relative to the hand wheel by a worm and wheel arrangement so that increments of feed can be finely regulated. For rapid adjustment the worm can be disengaged. The wheelhead has a total travel of 3 in. Surface finishes up to 1 microinch (CLA) can be obtained.

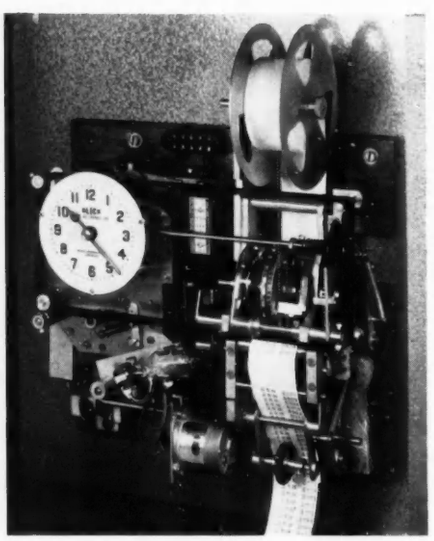
There are two wheel speeds, and two ranges of work speeds, each of six steps, giving coverage from 75 to 750 r.p.m. The wheelhead motor is 1½ h.p. and the workhead motor ½ h.p. The workhead has a fixed base and is provided with both live spindle and dead centre facilities. The maximum collet capacity is ½ in diameter. Maximum table travel is 13½ in.

Cylindrical work can be ground to an accuracy of 0·000,025 in using the standard live workhead.

COMPONENT RECORDING

An instrument that will record the passage of each component through a process together with the time, date and serial number, has been developed by Blick Time Recorders Limited, 96-100 Aldersgate Street, London, EC1. It was initially used in conjunction with a transfer machine to which it was connected electronically.

The record is printed on a continuous paper roll which passes through so long as the controlling machine is in operation, the roll being long enough for 14 days continuous running. When the machine stops the paper continues to run for three minutes thus making a definite gap in the list of records. The recorder is semi-portable and can be installed in an office or near the machine, as required.



Date, time and component number are automatically recorded on a continuous paper strip.

BENDING CALCULATOR

A calculation chart and an angle of bend indicator have been introduced by Chamberlain Industries Limited, Staffa Works, Staffa Road, Leyton, London, E10. The latter is shown attached to one of their two stage tube benders.

The chart is engraved in multicolour on a metal plate and is supplied ready for fitting to the inside of the lid of the carrying box provided for the machine and its dies. The angle of bend indicator consists of a chromium plated circular hollow rod graduated in inches which slides in a housing fitted in the top observation hole in the forming bed. One foot is adjustable and spring loaded to allow for manufacturing variations over the many years during which this particular type of frame has been produced.

Prior to the introduction of these attachments, ending to a required angle was usually carried out visually by trial and error or by the use of a protractor, but the new chart permits any degree of bend to be produced automatically without calculation, simply by reading from the sliding tubular indicator, the stroke of the ram in inches and referring back to the chart. In addition, the length of arc can be predetermined before bending so that the exact length of tube can be cut, thus effecting considerable material savings.

Continuing **Plant and Equipment**

VENDING MACHINE EXHIBITION

THE resurgence of the vending machine in Britain in the past five years has been reviewed recently in ENGINEERING (27 February, p. 266), as a background to the first international automatic vending exhibition and convention which took place last week (2 to 5 March) in London at the Old Hall of the Royal Horticultural Society. The exhibition was sponsored by the journal *Vending*.

Some 40 exhibitors took part, showing machines, accessories and components designed in Britain, Denmark, Germany, and Switzerland—but above all in the United States, where the progress of the automatic salesman has been unaffected by the shortages of consumer goods during and after the Second World War, which set back developments in this country.

Hot food automatic merchandising machine: W. M. Still and Sons Limited.

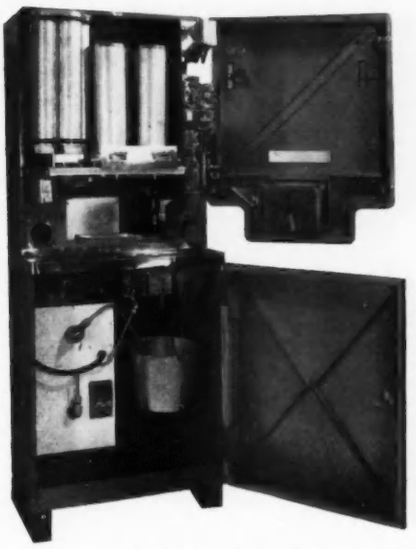
In this brief review of the exhibition mention can be made of but a few examples of the machines which are likely to be of interest to industry generally. Vending machine suppliers clearly foresee a big future for mechanised tea-brewing and dispensing in canteens and factories. Among tea-making machines on view were four new models making fresh tea from the leaf; they included 600 cup capacity machines, shown by two makers, Bramigk and Company Limited, 15 Creechurch Lane, London, EC3, and Parker and Dannen Limited, 54A Tottenham Court Road, London, W1. The Bramigk machine dispenses tea with or without sugar and refrigerated fresh milk, and brews six to eight cups at a time on a continuous cycle; whereas the British-designed Parker and Dannen machine brews each cup individually, in 8 seconds from the insertion of the coin, and presents the tea complete with refrigerated fresh milk and sugar. Also of British design and manufacture, is the larger "Canteen" automatic tea service shown by the Automatic Canteen Company Limited, 5 Bulstrode Street, London, W1, with a capacity for 750 cups—with or without milk and sugar.

On a smaller scale is the No. 1 tea machine shown by the British Automatic Company Limited, 14 Appold Street, London, EC2, which does not require a mains water supply, although it does, like the larger machines, operate from mains electricity. Water is stored in a 5½ gallon urn, milk in a 5½ pint container, and the machine has a capacity of 90 cartons containing tea, sugar and spoon. The coin mechanism will not accept coins until the water is boiling or when the tea packet supply is exhausted.

In addition to these machines, specially adapted for British tastes, there were cheaper and simpler types of hot drink dispensers on view. These machines do without fresh milk supplies, which create complications of maintenance and refrigeration, in favour of "instant" powdered ingredients. Machines of this type were the 200 cup tea/coffee machine of American design, which will be made under licence by Autobars Company Limited, 178 High Holborn, London, WC1; and the Mills beverage service, with a 500 cup capacity, which is available for tea, coffee, or chocolate.

Whether or not the completely automatic canteen will ever become popular in Great Britain is rather doubtful. Such installations, however, have a useful part to play in industries where a 24 hour shift service is worked and where conventional canteen arrangements are uneconomical, as, for instance, in the Margam works of the Steel Company of Wales, which has recently changed over completely to automatic food dispensing, using a battery of some 250 machines supplied and maintained by Vendepac Limited. In effect, these machines are hot and cold store cupboards, the food being cooked in the company's own kitchens. Similar types of machines to these were on view at the exhibition, as well as machines for hot canned food. Also on view was a hot food dispenser of a type new to this country, which is to be made under licence by W. M. Still and Sons Limited, 29/31 Greville Street, London, SE1. This machine offers a choice of two hot meals. The food is kept in a refrigerated compartment at 32° to 40° F until meal time approaches, when it is heated—in the same compartment—to a preset temperature for 50 minutes, after which any unconsumed food is re-cooled.

Squash-O-Matic machine for dispensing hot or cold drinks: Allied Produce Company Limited.



What the inside of a coffee machine looks like: The Automatic Canteen Company Limited.

At the Steel Company of Wales' automatic canteen, sales of milk have, increased perceptibly since the introduction of milk-vending machines. There were a number of such machines to be seen at the exhibition, such as the now well-known Vendo machine, made in this country by Joseph Sankey and Son Limited, Wellington, Shropshire, which dispenses milk by the carton; and the Cup-O-Matic bulk milk machine made in England by the Allied Produce Company Limited, Bristol, which dispenses milk in a cup, either plain or with a choice of two flavours, selected by press button, from refrigerated churns. The Squash-O-Matic machine made by the company, and shown alongside, offers the choice of three soft drinks—cold in summer or hot in winter.

Turning away from food and drink—from the sublime to the sinister: a development now available to ease the task of industrial security officers in keeping a check on visitors and employees is a "photo identification studio" shown by Photome Studios Limited, Manchester Square, London, W1, and made under licence from the Autophoto Company, Los Angeles, USA. Four photographs are taken over a period of 20 seconds of the subject and his identifying "number," which is inscribed on a bar placed in front of his chest. The photographs are recorded on continuous reversal paper strip, which is fed into a carrier and then through 14 processing tanks, and the processed picture is delivered in three minutes.

Continuing **Plant and Equipment**

ELECTRICAL ENGINEERS' EXHIBITION

THIS year's Electrical Engineers' Exhibition is to be held at Earls Court, London, from 17 to 21 March. More than 430 firms have taken space. The exhibition is sponsored by the Association of Supervising Electrical Engineers and the opening ceremony is to be performed by Lord Brabazon of Tara, who this year is president of the Royal Institution. In size the exhibits range from a 40 ton diesel electric locomotive to a microswitch weighing $\frac{1}{28}$ oz. It is fitting that in the year that marks the centenary of Big Ben one of the exhibits should be the largest electric clock in the world. With a dial 60 ft in diameter it will be suspended from the roof and will be controlled by a master clock on the Synchronome stand. The movement is electrically wound every hour and is released every half minute. Current consumption is less than one-third of a unit per day.

Another celebration this year is the Jubilee of the Illuminating Engineering Society, and there will be special features devoted to lighting. Included among these is the first presentation of a new display technique which has been called Aurama. This is somewhat on the lines of the Son et Lumière displays that have proved so popular, but is indoors and the whole effect is produced electronically. Like the Dioramas of 150 years ago the effects are obtained by changes of light, but this time against an abstract background and coupled with stereophonic sound. Aurama displays will be given in the Cromwell Hall at frequent intervals throughout the exhibition.

There are two other major lighting displays in the exhibition. The first is a feature of 4,000 changing lights arranged to demonstrate the possibilities of control, and the second consists of a series of shop windows in which are displayed goods of many types ranging from glassware to books, furnishings and rugs. The windows are arranged along both sides of an arcade in the middle of which is a grass strip with modern street lighting columns. The accent will be on the improved use of lighting rather than on more lights. There are ten windows in all, with the lighting in each arranged by a different firm.

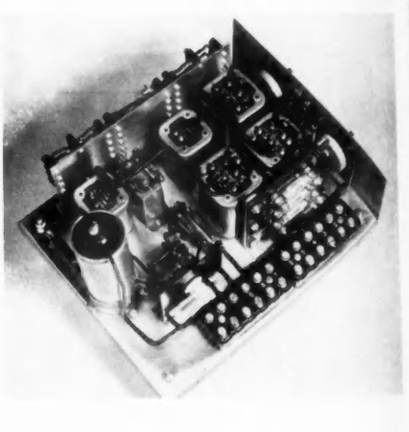
Voltage Regulator and Welding Controller

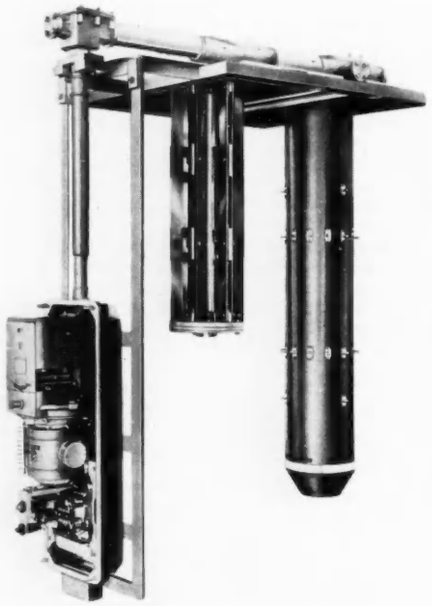
Heavy switchgear, motors and electronic equipment are all featured on the stand of the British Thomson-Houston Company Limited, Rugby. Their largest exhibit is the 40 ton diesel-electric locomotive in the forecourt, and the semiconductor field is represented by typical rectifier stacks as well as by a transistorised voltage regulator.

The regulator is for use with single unit self-contained alternators with ratings up to 100 kVA at 50/60 cycles. Control is given to within 1 per cent of the rated value. The equipment consists essentially of a Zener diode voltage sensitive circuit, a transistor amplifier, a rectifier supplying the exciter field power, and a stabilising circuit. The voltage sensitive circuit examines the alternator terminal voltage and produces an error signal when the terminal voltage departs from its nominal value. This error signal in turn controls the exciter field through the transistor amplifier in the correct sense and degree to restore the alternator voltage. Transient negative feed-back of the exciter armature voltage into the amplifier circuit provides damping of the voltage recovery following load changes. All components are rated for tropical conditions and are not affected by vibration.

The synchronous welding equipment exhibited by the same firm is designed to control the welding time and current of a spot- or seam-welding machine. In the case of the former the range of control available is from 1 to 90 cycles heat time in 1 cycle steps; and for the latter from 1 to 9 cycles heat time and 1 to 9 cycles cool time, both being adjustable in 1 cycle steps. Time selection is carried out by positive action switches which are connected in a digital circuit using Dekatron tubes to control and also to display the selected times. Heat control is by phase shift and either of two systems may be selected: manual control by a rheostat; and automatic control in which the current is automatically selected and maintained constant irrespective of substantial changes in load impedance or supply voltage.

Transistor voltage regulator.





Tap Changer

One of the items on the stand of Transformers (Watford) Limited, Sandown Road, Watford, Hertfordshire, is an air cooled fireproof transformer with Class C insulation. The unit is rated for 750 kVA 3 phase 50 cycles and has a ratio of 11,000/430 V. The insulation is made up of glass and asbestos with porcelain coil spacers, and impregnated with silicone varnish.

Another item which is on view for the first time in this country is a Jansen type on-load tap changer. It is shown in the accompanying illustration. The design makes it suitable for cover mounting, leaving the transformer tank sides free for cooling equipment, cable boxes, etc. The model exhibited is suitable for 18 steps giving fully automatic regulation on a 10 MVA 33 kV 3 phase transformer. It will withstand a pressure test of 121 kV and an impulse level of 242 kV with a $\frac{1}{50}$ micro-second wave. It is shown complete with the drive mechanism.

Jansen type tap changer.

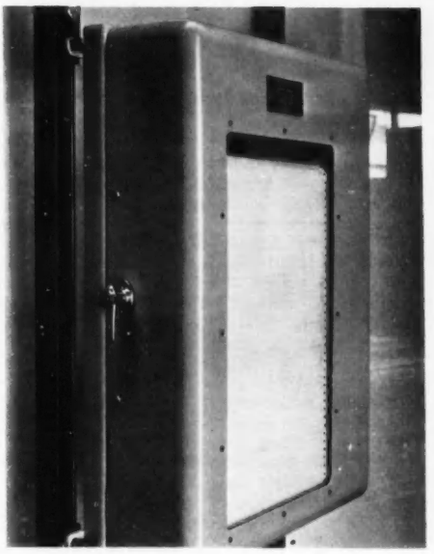
Two-Speed Motors

One of the motors on view from the Metropolitan-Vickers ranges will be a 30/15 h.p. example of the pole-modulated tapped winding form developed by Professor G. H. Rawcliffe. The combination of poles in this machine is 8/10, but other combinations are possible as long as the ratio does not exceed 1·5 to 1. There are six connecting leads to a standard switch unit of the type for controlling a tapped winding induction motor. The great advantage of the Rawcliffe machine is that only one winding is needed, where others require two to give the two speeds. This results both in a reduction in size and also in improved performance at both speeds. The motor size is not limited with this type of winding.

Mine Hoist Recorders

A very wide range of equipment will be displayed by the Metropolitan-Vickers Electrical Company Limited, Trafford Park, Manchester 17, including switchgear, motors, infra-red heaters, recorders and meters. One of the recorders on show is the quick response d.c. instrument developed to meet the need for immediate recording for testing and adjusting control systems and the like. The writing elements are the permanent magnet moving coil shuttle mounting type. The other recorder has been produced for pit-head winding gear to record the number and duration of winds, the winding speed, the decking or changing interval, the starting time, and the time taken for special operations such as shaft or rope inspection and shaft timbering. It is also possible to record the direction of wind and from the record to detect any delay or failure to operate to a desired schedule.

The electrically actuated pen records speed more accurately than mechanical governor controlled types and is easily detachable for inspection or filling. The record for the previous hour can be viewed through the Perspex window and the complete record can be examined without removal. As only electrical connections are needed, the recorder can be installed in any desired position, without regard for mechanical drives.



Winding recorder for mine hoists.

Breaker and Switch

On view for the first time on the stand of George Ellison Limited, Perry Barr, Birmingham, are a new air-insulated circuit-breaker and an oil switch. Both are for 11 kV systems.

The circuit-breaker is rated for 250 MVA and is only 24 in wide. The current rating is 400A. Vertical isolation is used and the contacts, which have a parallel wiping action, are immersed in oil in a three-division steel tank. Gases are discharged to the rear. The air insulated bus-bars are rated at 1,200A and are made in standard lengths. For easy access the voltage and current transformer terminal chamber is located at the rear. The current transformers are encapsulated and the voltage transformers can be isolated from ground level. Closing can be by hand, by a charged spring or by solenoid; either remote or local control can be employed.

The oil switch has a capacity of 400A, both carrying and breaking. It will make against 250 MVA. Operation is manual by charging and releasing a spring by one movement of a handle, the actual operation being independent of the operator. There is a single break per phase. Provision is made for earthing and for a test position, there being full interlocking for safety.

Air Insulated Switchgear

One of the new items to be displayed by Ferguson Pailin Limited, Higher Openshaw, Manchester, is the type BVPI7 single bus-bar air-insulated metal clad switchgear for use up to 11 kV. The units are fabricated and are designed for extension on both sides using similar or different units. The breakers are arranged for integral earthing, and the bus-bar and feeder shutters are independent. The breakers are mounted on trucks which incorporate the raising and lowering devices. They are fitted with round tanks of which the top plate is aluminium alloy and includes an earthing contact. The mechanism can be direct hand-operated spring assisted, or spring or solenoid operated.

Shot Fixing Tool

The Mark 4 Superdynamic cartridge operated fixing tool is an addition to the range made by F. H. Bourner and Company (Engineers) Limited, Manor Royal, Crawley, Sussex. Other fixing tools on show include hammer operated models of which one is particularly suitable for attaching small electrical fittings to brick, breeze or concrete.

The Mark 4 tool is breech loading but has manual ejection. It is also well silenced. It will drive fixing bolts into concrete, brick or steel; an example quoted by the makers is the driving of fixing bolts into a concrete roadway to take the steel curb shuttering. The bolts are simply driven through the bracket holes as required, thereby avoiding either casting the bolts in position when the concrete is poured, in which case considerable accuracy of placing is required, or cutting out the poured concrete and subsequently grouting the bolts in place. Shot driven, each bolt takes about one minute to fix and nuts can be screwed on immediately.

Control Switches

A wide range of control switches will be shown on the stand of Honeywell Controls Limited, Ruislip Road East, Greenford, Middlesex. Part of the display will be thermostatic controls for heaters up to 4 kW and there are two new limit switches and what the firm call a sub-sub-miniature Micro switch.

One of the limit switches is a plug-in unit with an industrial housing and a wide choice of mounting positions and actuators. The other, the type LS, has been developed to be compact in size while capable of handling a heavy loading. Again there is a choice of actuators—roller arm, rod, plunger or coil spring. The sub-sub-miniature switch is stated to be half the size of the previous smallest switch; it measures 0·5 in by 0·35 in by 0·2 in, giving a volume of 0·035 cu. in for a weight of $\frac{1}{16}$ oz. The contact action is single-pole double-throw and it can be wired for normally open or normally closed. The actuator used with this switch can be plunger, roller or lever type.

Sub-sub-miniature Micro switch.

Packaged Drive

Examples from the new range of stationary field eddy-current couplings as well as from their older models, form part of the exhibits on the stand of Heenan and Froude Limited, Worcester. The new range includes both air and water-cooled types with power capacities up to 50 h.p. They are mounted integrally with standard flange fixing squirrel cage motors to form a very compact drive unit.

The Adjusto-Spede fractional h.p. drive is shown in the accompanying illustration. It is designed to give an infinitely variable speed over a wide range from a.c. mains. The equipment comprises a fixed speed single or three-phase induction motor mounted integrally with an eddy-current variable speed coupling in one drip proof casing. The motor and the input member of the coupling therefore run at a fixed speed while the output member runs at speeds governed by the control unit. A small tachometer generator is built into the housing, and the variable speed shaft extends through the unit so that the variable speed drive is available at both ends. The overall length of the unit is approximately 15½ in and the diameter of the housing about 6½ in. The controller measures 5 in by 5 in by 6½ in and can be mounted at a remote point. It has a single valve circuit designed to afford close speed control even for large load changes. The controlling current required is small so that low powered components can be used. The wiring is colour-coded to simplify installation.

Packaged variable-speed drive.

Companies in the News

Vickers Race Krupps to Moscow

An order worth £2·25 million for a complete chemical plant has been obtained by Vickers-Armstrongs (Engineers) Limited in Moscow in the face of fierce competition, particularly from Krupps. The supply of plant will be undertaken with another British firm, Highpolymer and Petrochemical Engineers, who are designers and consultants. The order is still subject to "contract conditions" but Vickers expect to finalise it shortly. There is also a possibility that Vickers might be given a very large order for three complete new sugar plants for the USSR.

The sales director of Vickers-Armstrongs (Engineers), Mr. Robert Wonfor, has been very active in seeking business in the USSR and has demonstrated that there are good orders to be won, provided the main contractors are willing and able to engineer complete enterprises. Evidence of this was provided by the major contracts obtained by the British consortium Rustyfa, for rubber tyre factories. This preference for comprehensive deals is not limited to the Soviet Union—the same applies to India, Argentina, and even this country. The trend of demand in most export markets is increasingly towards application engineering and fully integrated designs. This will help large groups, such as Vickers, and will promote the formation of consortia for individual projects and also for general export activities.

Russia has also placed orders for machine tools, with Coventry Gauge and Tool Company, Dowding and Doll, and Newall Engineering. Although the orders are small—between £30,000 and £35,000—they were described by the spokesman of the British Machine Tool Trades Association as "symbolic and vital" for the industry. The machines were until recently under trade embargo.

Parsons Prize

In view of the growing pressure exerted by the American electrical engineering industry on the Office of Civil and Defence Mobilisation to secure an embargo on the importation of most types of heavy equipment, it is interesting to note that C. A. Parsons and Company, whose tender for a 500 MW turbogenerator was accepted by the Tennessee Valley Authority, have previously supplied generating equipment to the United States without arousing such opposition. The company have pointed out that they first supplied a 25 MW generator in 1912 to Commonwealth Edison, for their Fisk Street power station which proved to be larger and more efficient than any set in the world at that time. Ten years later they supplied a 50 MW set to the same company for their Crawford Avenue power station, which on test after 18 months' operation showed a thermal efficiency of 34·02 per cent, a remarkable figure at that time.

The 500 MW machine at present on order for the TVA is claimed to be the largest turbogenerator projected in the world apart from a 550 MW unit which Parsons are building for the CEGB station at Thorpe Marsh. The American industry lodged its appeal for a general embargo on national security grounds more than a year ago, but the order to Parsons is the first steam-turbine contract to be placed abroad. It has been followed by a successful bid by the Swiss Brown, Boveri for two steam turbines required by the Los Angeles power commission. In both cases the American tenders exceeded the overseas bids by really substantial amounts: Parsons bid was $12 million which was said to be $5 million below the lowest American tender, while Brown, Boveri are reported to have quoted $9·3 million against the American General Electric tender of $14·8 million.

An import embargo is sought not only on steam turbines but also on transformers, generators, circuit breakers and hydraulic turbines. President Eisenhower has expressed the view that the American manufacturers are running the risk of pricing themselves out of both home and export markets and it is difficult to see how the industry's appeal on national security grounds can be substantiated, particularly since the TVA have announced that in the case of the Parsons contract repair facilities are available in the event of an emergency in Canada.

Take-Overs Take Root

Changes in the boards of the two major companies to be taken over in recent months—the British Aluminium Company Limited and F. Perkins Limited—have been announced. As expected, they have been most extensive in the case of BA, whose chairman, Lord Portal, and deputy chairman, Mr. Geoffrey Cunliffe, have left the boards of the parent company and all their subsidiary and associated companies.

The new chairman is Sir Ivan A. R. Stedeford, and Mr. Richard S. Reynolds has been elected a director. There have been other changes involving a dozen or so new appointments. At the research laboratories, Chalfont Park, Mr. H. W. L. Phillips retires next September; Mr. A. C. Coates has been appointed assistant director of research (chemical) and will deputise for the director of research, Dr. Pearson, in his absence. Mr. P. C. Varley becomes assistant director of research (metallurgical), Dr. C. E. Ransley will be given the title of senior research metallurgist and Dr. F. A. Champion that of senior research chemist. All appointments are effective from 12 September next. At the rolling mills, Mr. J. A. Richmond has been appointed deputy manager at Falkirk with effect from 1 July, and has been nominated to succeed Mr. Field as manager when the latter retires in January, 1960. Mr. T. D. Rees has been appointed deputy manager at Latchford as from 1 May.

Following the take over of F. Perkins by Massey-Ferguson, Colonel W. E. Phillips, chairman and chief executive officer of that company, and Mr. Albert A. Thornbrough, their president, join the board. Sir Richard Yeabsley and Mr. G. P. Ritchie have resigned. Mr. Frank Perkins remains chairman but relinquishes his position as joint managing director. Mr. M. I. Pritchard becomes sole managing director.

Rotodynes for New York

The first United States order for vertical take-off airliners, of a design pioneered in this country, has been placed by New York Airways. They have ordered five Fairey Rotodyne aircraft, to be delivered by the spring of 1964, and have acquired an option on a further 15. The order was disclosed to the United States Civil Aeronautics Board during hearings of an application by New York Airways for renewal of its five-year licence to operate helicopter services from New York to various towns in the states of New York, Connecticut, New Jersey and Massachusetts. The company also flies between the three principal airports in the New York area, Idlewild, La Guardia and Newark.

The aircraft ordered will be built in Britain, but the Rotodyne may later be produced in the United States. Mr. Robert Cummings, president of New York Airways, said that plans were well advanced for Kaman Aircraft Corporation, Fairey's representatives in the United States, to go into production.

The New York Airway's Rotodynes will be bigger and faster than the 48-passenger prototype now flying. They will carry 57 passengers at more than 200 m.p.h. over a 250 mile stage length. The maximum load will be 65 passengers or 18,000 lb of freight over a 120 mile stage length; the maximum range with unspecified payload is stated to be 650 miles. The power units will be two 5,000 h.p. Rolls-Royce Tyne propeller-turbines, instead of the two 2,800 h.p. Napier Eland propeller-turbines used in the present aircraft. The rotor diameter will be increased from 90 ft to 104 ft. The first order for a Rotodyne by a Canadian firm, the Okanagan Helicopters Group of Vancouver, was announced last September. British European Airways have placed provisional orders for six machines—"subject to agreement on final specifications" with an option on a further 14. If this order is confirmed, the Ministry of Supply will pay half the remaining costs of development, up to a fixed maximum, and will make a levy on sales related to the Government contribution.

Americans Buy Japanese Cars

The latest foreign car to invade the American market comes from the Far East. It is the Toyopet Crown Custom made in Japan. The model now on sale in the United States is a six-passenger saloon selling for less than $2,500—about £850. It offers American buyers most of the features which Detroit has led them to expect, with many of the things now regarded as extras thrown in. White-walled tyres, heater, full anti-corrosion sealing, foam rubber seats and deep pile carpets are all included. Toyota Motor Distributors Incorporated report orders for 250 of the new model since it made its appearance at the Chicago Motor Show last month.

The first model seen in America was the standard version made for Japanese roads. Although somewhat austere in line, 374 have been sold in the Pacific coast states. A companion vehicle the Toyota Land Cruiser, a four-wheel drive, jeep-type vehicle, is also now being sold in the United States. Toyota has 35 dealers from Seattle down to the Mexican border. Some of these are among the best known firms in the region. From the results so far obtained in America, Toyota expect a substantial increase on the present demand for about 100,000 vehicles a year.

Cool Catch

At a cost of £2 million, representing land and basic facilities, the Board of Trade have landed a "catch" for the under-employed area of South Wales. The company which has taken the bait is Pressed Steel, who adopt the name Prestcold for their primary domestic product, refrigerators.

At a ceremony on 4 March, Mr. John Rodgers, MP, Parliamentary Secretary to the Board of Trade, caused the cornerstone to become "well and truly laid." The site is at Crymlyn Burrows near Swansea, and has its longer side parallel to the double-carriage coastal road. Present at the ceremony were 200 representatives of Government departments, industrial and business concerns, and local authorities; but perhaps more important, about 50 local people had come to see their new company, who it is said, in employing 4,000 by the early 1960's, will be one of the largest single employers of labour in Wales. Sir Miles Thomas, chairman of the Development Corporation for Wales, paid tribute to Welsh labour, and Mr. J. R. Edwards, managing director of Pressed Steel, declared the workpeople "their old friends."

On this site, under roofs rented from the Board of Trade under the Distribution of Industry Act, the company plan to invest £2¾ million in plant and fittings for manufacture of refrigerators. Existing facilities at Cowley and Theale (Berkshire) will be moved to Wales, thus permitting increased output of car bodies from those works. Commercial production of complete refrigerator units will be under way by 1961—"there is a tremendous potential," said Mr. E. G. Rowledge, a senior company director, "for in this country only 14 per cent of the 'wired' homes . . . have this appliance."

Automobile Engineering

Cars for an International Market

By Gordon Wilkins

GENEVA 1959

AFTER more than three years' testing of prototypes in climates from tropical Africa to northern Sweden, Fiat presented at Geneva this week the new model which replaces the four-cylinder 1400 and 1900. It will be known as the 1800 or 2100 according to engine size but apart from cylinder bores and pistons there are few differences between the two.

The car is almost entirely new, structurally and mechanically. The unit body-chassis structure is in the current angular Latin style, with a broad, cowled front recalling American Chrysler group cars. Body styling was done in Fiat's own styling studios, now run by Boano under Ing. F. Rapi, but Farina was called in as consultant. Front suspension by torsion bars is basically similar to that used on the Morris Minor and more recently on Chrysler group cars. A single lower track control arm is splined to a longitudinal torsion bar, with a diagonal tie to take the braking force. Above is a pressed steel wishbone. Ball joints form the steering pivots and there is an anti-roll bar.

The Lancia Appia has had its engine power increased to 48 b.h.p.

Rear suspension is developed from that on the 1400, with a rigid axle carried on flexible radius arms formed of steel blades clamped together like a leaf spring with the master leaf in the middle. Lateral location is by a Panhard rod which is connected to an offset bracket behind the differential casing by a rubber bush which is perforated to allow slight lateral play but remains firm vertically. A small pad over the axle nose-piece engages with a rubber buffer on the frame to prevent the axle tilting through torque reaction between pinion and crown wheel, and the ends of the coil springs are gaitered to prevent transmission of road rumble.

New Fiats with six-cylinder engines of 1,800 or 2,100 cc replace the four-cylinder 1400 and 1900 models.

The engine is an efficient short six-cylinder unit with inclined valves operated by pushrods and rockers on twin rocker shafts. The combustion chambers are roughly hemispherical, but are in fact compounded of sections of four spheres. The plugs are accessibly placed alongside offset exhaust valves, which keeps them outside the single rocker box

The head, in aluminium, is secured by the minimum number of holding-down studs to a shallow iron block finishing level with the centre line of the crankshaft. The latter runs in five copper-lead thin-shell Vandervell bearings. The engine runs safely up to 6,000 r.p.m. A twin-choke downdraught carburettor is mounted transversely on a cast aluminium distribution box with internal compartments dividing the flow to two separate three-cylinder manifolds. The six-branch exhaust is on the opposite side of the engine and as inlet manifold heating cannot conveniently be arranged, an extension pipe from the air cleaner is provided to pick up warm air from the region of the exhaust manifold in cold weather. A hollow light-alloy fan pulley acts as a centrifugal oil filter as on the Fiat 500, and the five-bladed fan is in moulded plastics.

The two engines differ only in bore size. The 1800 unit (72 by 73·5 mm, 1,795 cc) gives 85 b.h.p. SAE rating, representing 47·4 b.h.p. per litre. The 2100 unit (77 by 73·5 mm, 2,054 cc) develops 95 b.h.p. SAE rating, or 46·3 b.h.p. per litre, compression being 8·8 : 1 in both cases. Maximum speed is said to be 87 or 93 m.p.h. according to engine.

The clutch housing is in light alloy and the gearbox is an inverted iron casting with closed top, the bottom face being sealed by a finned light alloy casting which forms a shallow oil sump. All four speeds are synchronised.

Brakes have radially finned aluminium drums with iron liners. Front brakes have the Baldwin booster, which Fiat were the first to use, and in the rear brake line is a new device which progressively reduces the rate of pressure rise, so that braking effort is concentrated more on the front wheels during heavy braking, to reduce the tendency to lock the rear wheels.

The Fiat rear suspension has a rigid axle carried on flexible radius arms.

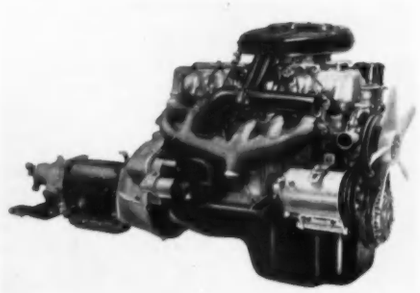
Equipment is complete down to fog lamps and a warning light which shows if the car is driven away with the handbrake on. Door locks are the Wilmot Breeden Zero Torque type made in Italy under licence.

The car was designed under the general direction of Ing. Dante Giacosa who, following a spell of sick leave last year, has been relieved of responsibility for production problems, leaving him free to concentrate on design and development of all Fiat road vehicles. Aurelio Lampredi who was formerly chief designer with Ferrari did much of the work on the engine.

Lancia have just adopted Dunlop disc brakes for their V6 2¼ litre Flaminia which in short chassis form is said to do 114 m.p.h. Power of the little 1,090 cc V4 Appia engine has been increased by 10 per cent to 48 b.h.p.; the front brakes now have two leading shoes and the body has been brought up to date with new front end panels, a wide grille and new tail lamps. Wheel diameter is reduced by an inch, slightly lowering the centre of gravity.

In Germany, the NSU Prince economy car seems to have established itself. Power of its 583 cc overhead camshaft twin cylinder engine is held down to 20 b.h.p. to qualify for low insurance premiums, but for export the saloon is now available with 30 b.h.p. like the sports coupé, and there is a new gearbox with synchromesh for all four speeds.

The small British Berkeley sports car with metal-reinforced plastics structure also receives a big increase in power from the use of twin-cylinder Royal Enfield engines of 692 cc, giving 40 or 50 b.h.p., as an alternative to the three-cylinder two-stroke Excelsior producing 30 b.h.p. from 492 cc. The more powerful engine gives a power to weight ratio approaching 160 b.h.p. per ton.



The Fiat 2100 engine develops 95 b.h.p.

One of the few cars from Eastern Europe to win a place in Western markets, the small Czechoslovakian Skoda, previously known as the 440, has been improved and renamed the Octavia. Front suspension is now by coil springs instead of a transverse leaf and is carried on a detachable subframe on the end of the tubular backbone chassis. There is a choice of a 1,089 cc engine giving 43 b.h.p. SAE rating or a 1,221 cc unit producing 47 b.h.p. on 7 to 1 compression ratios, with 8 to 1 ratios available for export.

In Parliament

WORK FOR THE ELDERLY

Employment problems concerning men and women in the older age groups were reviewed in a five-hour debate in the House of Commons last Friday. The debate was introduced by Colonel Richard Glyn (Conservative) who moved that the House recognise the importance of making full use of the working capacity of older persons, in view of the gradually rising average age of the population; welcome the encouragement that the Government had given to research on the subject; and urge that the Government should promote further research on the same lines.

He said that, according to official figures, it seemed highly probable that, by the end of the present century, the expectation of life in Britain would be at least 50 per cent longer than it was in 1901. It followed that if everyone who reached pension age were to retire immediately, the burden thereby placed on those of working age would soon become oppressive.

In most parts of the country there appeared to be little difficulty in placing elderly skilled tradesmen who retained all their faculties and who could make use of their skills, or those elderly unskilled workers who had retained their health. In some areas, however, great trouble was experienced in placing middle-aged clerical workers, and middle-age employees of managerial status who sought work at the level to which they were accustomed. Older people who wished to continue working should be given every assistance and encouragement.

CHANGING JOBS AT 45

Mrs. Evelyn Emmet (Conservative) said it was amazing to think that the expectation of life in 1901 was only 49 years for a man and only 52 for a woman. By 1950, life expectations had risen to 66 for men and to 71 for women. They had risen further since then.

Advances in medicine and in other directions were such that it might well become the rule rather than the exception for men and women to change their jobs at the age of 45 and 50, and refresh themselves by a completely new start in life. The subject was an urgent one and should be studied with imagination and understanding by the trade unions, the British Employers' Confederation and the medical profession. There was concern in local government about recruiting, but a number of positions both there and in Government offices could be turned over to elderly people after a short period of training.

Mr. Charles Doughty (Conservative) felt that the problem of dealing with unskilled elderly persons was the greatest. As a general rule, unskilled labour required more physical strength, although there were exceptions. Younger people were generally considered, probably wrongly, to possess greater physical strength, and accordingly, there was a natural reluctance on the part of employers to engage older persons for unskilled work.

Sir Keith Joseph, Bt. (Conservative) urged the Government to consider the arguments in favour of having a fixed age for the drawing of pensions, without retirement conditions, without an earnings rule, and without an increment.

EFFECTS OF AUTOMATION

It was pointed out by Mr. Alfred Robens, formerly Minister of Labour and National Service in the Labour Government, that to provide work for elderly people the first requirement was a high level of employment. The Ministry of Labour should consider the possibility of providing special training, perhaps of three months' duration, for elderly folk who could do only one kind of job and who lived in areas of large-scale unemployment. He believed the question of finding work for the elderly to be one for administrative action, largely through the Ministry of Labour.

Mr. H. Hynd (Labour) referred to the special difficulty of finding employment for elderly persons in Lancashire. The trouble arose not only in the cotton industry, but in other industries as well, including those of engineering, shipbuilding, ship-repairing, and the docks. Mr. R. Gresham Cooke (Conservative) felt that the effects of automation might be to make the working day shorter. It might then be possible, and even desirable, that people should go on working for a longer period, which they could easily do, well into their old age.

CALL A CONFERENCE

Replying for the Government, Mr. Richard Wood, the Parliamentary Secretary to the Ministry of Labour, said that recently an increasing amount of thought had been given to the problems of employing workers from the age of 40 upwards. Not only was the proportion of older people in the population rising, but this was accompanied by an increase in the number of older people at work.

Population prospects suggested that there would be a material advance in the numbers of men and women over 55 at work, but, also, a decline in the numbers aged between 35 and 54. It was the Government's intention to continue their active interest in the problems of research on this matter and they would try to make regular arrangements for liaison between the Ministry of Labour and the research organisations.

Mr. Wood said he had decided that the best means for effecting such liaison would be to have a regular meeting of an inter-departmental committee representing the ministries interested in this work. The best means of providing a link between the research departments and industry would not be to enlarge the committee, but, from time to time, to call a conference, which might be a one or two-day affair, to discuss the whole range of problems, about which industry would contribute its views and upon which the research workers would tell industry how research on such lines would be possible.

BRITISH SCIENCE JOURNALS

A plea was made by Mr. R. Gresham Cooke (Conservative) that the Chancellor of the Duchy of Lancaster should assist and encourage the distribution of the journals of Britain's principal learned societies in foreign countries and the Commonwealth. He asked the Chancellor, Dr. Charles Hill, if he were now in a position to state his proposals in this connection.

Dr. Hill said that the British Council already made use of the journals of learned bodies in this country by providing copies of them in the Council's overseas libraries and reading rooms. The Council presented copies to learned institutions overseas and displayed copies in their exhibitions of specialised periodicals. As mentioned in the White Paper which had just been published, entitled *Overseas Information Services* (HMSO, Cmnd. 685, price 6*d*), these services were to be further expanded.

Consideration was being given at the present moment, by himself and the Government departments concerned, as to what additional measures could be taken to promote the circulation of such journals overseas.

RAILWAY ORGANISATION

The policy for the railways, set out in the recently-published White Paper *Railway Reorganisation* (HMSO, Cmnd. 9191, price 9*d*) has been progressively applied, according to an answer by Mr. Harold Watkinson, the Minister of Transport and Civil Aviation. He told Mr. J. W. W. Peyton (Conservative) that all the area boards were functioning fully, and that the day-to-day management of the railways and the responsibility for organisation within their respective regions had been delegated to them.

Responsibilities allotted to the boards included the production of revenue budgets and the promotion of business. In all regions, the operating and commercial functions had now been merged, and further decentralisation on a line or area basis had been introduced. This procedure gave greater local autonomy, including a wider latitude in applying the freight charges scheme, and in obtaining and in carrying traffic.

Members of the area boards who had entered the railway service from industry and from public activities were making a most valuable contribution.

NATO SCIENCE STUDENTSHIPS

The North Atlantic Council have decided to finance a science studentship and fellowship programme, to commence this year. Mr. Harmar Nicholls, the Parliamentary Secretary to the Ministry of Works, told Sir Henry d'Avigdor-Goldsmid (Conservative) that these awards would be made by the Department of Scientific and Industrial Research, in consultation with other interested Government bodies, to British subjects normally resident in this country.

Under the programme, the United Kingdom proposed to provide increased opportunities for study, research training, and experience for post-graduate and post-doctoral students in science and technology, including the medical and agricultural sciences, industrial psychology and sociology. The scheme was intended to stimulate an international exchange of such students between countries belonging to the North Atlantic Treaty Organisation, though awards could be held in a student's home country, or even in a non-NATO country.

Giving this information in his capacity of representative in the Commons of the Lord President of the Council, Mr. Nicholls said that the value of these awards, and the conditions governing them, would be similar, in general, to those for DSIR studentships and fellowships. Provisions would be included to provide for the cost of travel and for a cost-of-living allowance.

Artificial Satellites

Answering a question by Mr. Roy Mason (Labour) about the advantages to be gained from proceeding with an earth-satellite programme, Mr. W. J. Taylor, the Parliamentary Secretary to the Ministry of Supply, said that the Minister had consulted informally a group of Fellows of the Royal Society. They had drawn the Minister's attention to the many advantages which would result from researches with artificial satellites, especially in respect to physical, astronomical and meteorological science. These Fellows could not, of course, cover the question of priorities as between such research and other claims on Government expenditure.

Combating Silicosis

New processes for combating pneumoconiosis and silicosis were referred to in questions put by Mr. Tom Brown (Labour). He was told by Mr. John Boyd-Carpenter, the Minister of Pensions and National Insurance, that a copy of "the full and interesting report" on these complaints by Dr. Howell had been sent to him by the General Council of the Trades Union Congress. The report would clearly require careful study before conclusions could be reached on its recommendations. Certain pneumoconiosis and silicosis panels were already using the technique of the Gough process in their examination of men suspected to be suffering from these diseases. The possibility of extending the use of the process was under consideration.

Non-Ferrous Mining

Suggestions were made by Mr. J. W. Ainsley (Labour) that financial assistance should be given to industries concerned with the non-ferrous mining potentialities of Weardale, County Durham. These mining possibilities had been listed in a paper presented by Professor K. C. Dunham to the Institution of Mining and Metallurgy in September last year. The full exploitation of the minerals at Weardale should be encouraged. Sir David Eccles, the President of the Board of Trade, replied that the exploitation of these non-ferrous minerals was a matter for private enterprise. Weardale was not an area coming under the Development Areas Treasury Advisory Committee.

The Human Element

Where To Do Research

Addressing the annual general meeting of the Association of Technical Institutions recently, Sir Harry Melville who is secretary of the Department of Scientific and Industrial Research, deplored the small number of post-graduate research students in technical institutions. He pointed out that although the universities would always have a unique appeal for post-graduate work, the DSIR was anxious to encourage applications for grants from other organisations and from those with other than purely university qualifications. The new Diploma of Technology had already been recognised for this purpose.

Sir Harry was concerned that the pulling power of the universities might distort the flow of post-graduate effort into channels which would not fit into the country's technological effort as a whole over the next few generations. There is indeed a point beyond his remarks which could be given more thought than it gets at present. This is the wastage rate among post-graduate scholars at universities.

It is well known that for a variety of reasons the flow of young men into university research work is not satisfactory. Too many men of mixed merit get through. Again, too many men who would serve themselves and the country better if they left the academic world sooner, linger on because they fear the impact on themselves of a new environment. The result of the first problem is a high wastage rate because too many never finish their courses or never fulfil their earlier promise. The result of the second is a delay in industrial recruitment of good material which could probably soon earn its keep once it had made adjustments to environment. Those who have qualifications from technical institutions are probably less prone to these difficulties.

Labor Legislation

The disclosures in recent investigations by the United States Congress of connections between trade union officials and racketeers has stirred opinion both inside and outside the trade union movement. Beyond a certain point it is not a happy solution to dictate a minimum standard of conduct among union officials by legislation. But the precise point is difficult to find in a movement with such extremes of public responsibility and lawlessness as the American trade unions.

One consequence of the current public outcry against certain practices is that proposed legislation is based on the views of pressure groups both inside the union movement and outside it rather than on objective appraisal. The Kennedy-Ervin Bill has now passed the sub-committee of the Senate Labor Committee in the form endorsed by AFI-CIO, and will now go forward to the full Labor and Public Welfare Committee.

The bill remains a strong dish, however, even when certain compromises have been written into it. It covers the filing of reports on administrative practices with the Secretary of Labor in Washington; penalties for false returns, destruction of records and embezzlement; penalties for bribery; elections for union office; and prohibition of picketing for extortion. These are stern sanctions but probably necessary for a movement which has in some places a record of violence both in support of and in opposition to it.

One Square Metre Each

In less than fifty years the world's population will have grown to 6,500 million, if it continues to increase at its present geometrical rate. It has taken some 200,000 years to reach 2,500 million, but will only take thirty years to add another 2,000 million. In 1957 and 1958 the world's population grew by 90 million—as much as the entire population of Japan and twice that of France—and in the next two years a further increase of 100 million is expected.

The reasons for this amazing rate of growth, long discussed by population experts the world over, are analysed in a fascinating new study, *The Future Growth of World Population*, recently published by the United Nations. The key to it all is not, as might be supposed, a higher birth rate, but a dramatic drop in the death rate. At present, according to the report, three babies are born and two people die every second. In the next twenty years, four births and two deaths per second may be expected—and there are more than 30 million seconds in a year.

At the present rate of increase, the report concludes, in six hundred more years—little more than the time since the discovery of the New World—each human being will have only one square metre to live on: "It goes without saying that this can never take place; something will happen to prevent it" say the authors. Perhaps the colonisation of the planets, so dear to science fiction writers, will provide a solution; perhaps the theories of Malthus may come to dominate. Some comfort may be drawn from the knowledge that, at present, the 2,500 million people in the world could be accommodated—standing up—in the Isle of Wight.

First Among Partners

Sir Alexander Fleck, F.R.S., the chairman of Imperial Chemical Industries, has accepted the presidency of the Industrial Co-Partnership Association. He succeeds the late Viscount Cecil of Chelwood, C.H., who died last November.

The Association sets out to encourage and promote the practice of co-partnership principles in industry, and is supported by a large number of leading firms. Sir Alexander's leadership, which has already made itself felt in his own company's co-partnership schemes, will be invaluable to the association.

Directing the Inventive

A new managing director of the National Research Development Corporation, Mr. John Clifford Duckworth, has been appointed to succeed the Earl of Halsbury, who resigned as from 31 March this year. In their announcement of the appointment, the Board of Trade underline the excellent qualifications of the new managing director, who is only 42 years of age. After taking first class honours in physics at Oxford in 1938, Mr. Duckworth played a leading part in radar research and development during the war. After the war, he was engaged in fundamental nuclear physics research at Chalk River in Canada and at Harwell, and was later in charge of development and design at Ferranti of the guidance and control system for the guided weapon now known as "Bloodhound." In 1954 he joined the then British Electricity Authority with responsibility for the design, construction and operation of nuclear power stations, and is at present chief research and development officer of the Central Electricity Generating Board. His salary will be £5,000 a year, the same as his predecessor.

The Corporation exist to develop and exploit for commercial use inventions made in publicly-financed research bodies, such as Government research establishments and universities, and also inventions of public importance from other sources which are not being developed by industry. It may also promote or assist research which is likely to lead to an important invention capable of practical use. Its chairman, Sir William Black (managing director of Associated Commercial Vehicles), heads a most progressive and brilliant board which includes two Fellows of the Royal Society, Professor P. M. S. Blackett and Professor Sir Charles Dodds, and the chief scientist of the Ministry of Supply, Sir Owen Wansbrough-Jones.

Plant or Equipment

A rose by any other name would smell as sweet, but how is one to identify the rose without a perfume? This is figuratively the dilemma which faces the plant engineers, or so it seems to follow from the remarks of Sir John Hacking, recently the principal guest at the annual dinner of the Institution of Plant Engineers. He considered that there was no proper definition of a plant engineer, and his opinion is all the more worth consideration since the plant engineers have recently achieved the status of an institution.

In replying to Sir John, Mr. K. S. London said that a plant engineer was anyone who could take the responsibility for running and operating equipment. In a way this does not take one a great deal further, for one is bound to ask what equipment is. Here is a point of real substance for there has been long and serious confusion in this country as to what is plant and what is equipment. The problem bobbed up some years ago in a very practical form when the Wilson Smith committee sat to consider the question of quotas for the importation of machinery. They were forced to make their own definition of machinery, plant, and equipment.

It would be much to the advantage of engineers as a whole if some acceptable definition of these three could be agreed and put into circulation. At the present time they are used rather indiscriminately. It would be a small but significant achievement for the new institution if it could sort out this tangle of definition.

Subhuman Element

If all goes well and the experts' expectations are fulfilled, small monkeys may well become the first United States space pilots. A new type of school has been set up at Wright-Patterson AFB near Dayton, United States, where monkeys are being put through a rigid training programme by specialised staff of the Engineering Psychology, Unusual Environment Section, of the Air Force Research and Development Centre.

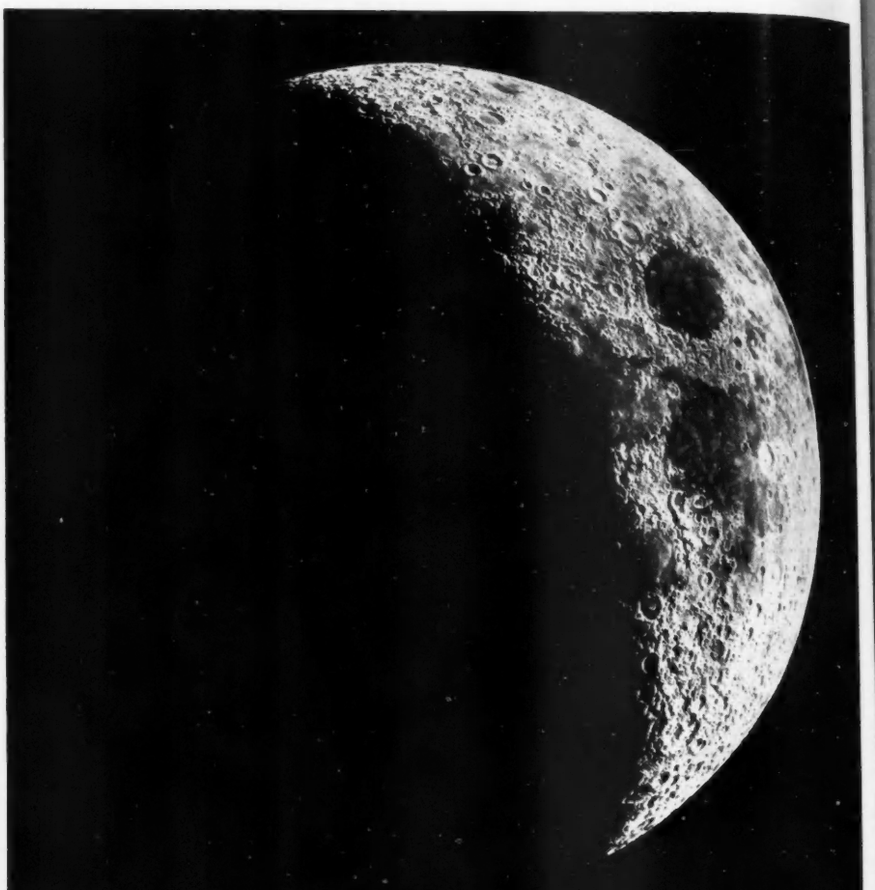
Human engineering research is said to be most advanced in the US Air Force. Primates make ideal guinea pigs for space environment research. Their cardiovascular and muscular systems closely match those of man. They have cone vision like man, which permits colour discrimination. In addition they are intelligent and can be trained for monitoring jobs.

Top of the form at Wright-Patterson is a serious young monkey named Aloysius. In barely two weeks he has mastered the art of lining up one sliding white block with another in response to a light signal. He is now learning to discriminate between different lights, buzzers, colours and shapes, and to respond correctly to each of them.

The object of this research is to discover how efficient man is likely to be in orbit or in outer space flight. US scientists are confident that survival is possible, provided reasonable precautions are taken, but have doubts concerning man's ability to monitor a number of dials and gauges under these conditions. Aloysius will help to answer their questions; will man, after exposure to space conditions for a period of time, be able to see, hear and respond? What happens to the mental process, and can it maintain vigilance for an extended period? What will be the effect of repeated space flights? Another question, so far unanswered, is why Soviet scientists use dogs.

Special Article

LUNAR JOURNEY



TWO PACKETS of instruments have passed near the moon; the first launched from the Soviet Union, the second from the United States. Both became planets. Soon other probes will follow—landing on, circling, or orbiting the moon, depending on the refinement of rocket technology. Basically these projects call for precise and delicate control of brute force; the enormous thrusts that lift a missile from the grip of earth's gravity must be adjusted within fine limits. In addition, the missile system must be reliable. As motor thrust and time of flight increase so does the likelihood of component failure. In fact the problems facing the rocket designer grow very rapidly with the distance his rocket has to travel.

The trajectories taken by a missile to the moon can vary greatly in length and configuration. At present, the procedure followed has been to provide a high speed in the first few minutes after lift-off and then to cut the motors and allow the instrument package to glide to the moon. Depending on the trajectory at motor cut-off, the package may hit the moon, encircle the moon and return to earth, pass the moon and orbit round the sun, or fail to reach the moon at all. With the use of a retro-rocket fired near the moon, the instrument package can be put into an orbit around the moon.

A great deal of computational work has been carried out on the best paths for a moon probe to follow. The Rand Corporation in the United States has produced a number of reports on the subject, and early Russian work was reported at the 1957 Congress of the International Astronautical Federation. In nearly all cases the calculations have been concerned with the passive part of the trajectory, with the aim of discovering the conditions under which initial errors have the minimum effect.

The Russian calculations (ENGNG., vol. 184, p. 642, 22 Nov. '57) showed that the minimum initial velocity over the first part of the passive section, 200 km from the surface of the earth, was 10,849 metres per second. Numerical integration by computer showed that if such trajectories reach the moon, it is only after about 100 or more rotations about the earth. The minimum velocity required to reach the moon on the first rotation in a non-rotating system of geocentric co-ordinates was found to be 10,905 metres per second. In the calculations of trajectories of vehicles that reach the moon it was found that the deviation of the trajectory from the moon's centre was a quadratic and not a linear function of small errors in the initial flight path. For trajectories in which the probe encircled the moon and returned to earth, it was also found that the deviation from the centre of the earth was a quadratic function of errors in the initial flight path. The more interesting trajectory of flight round the moon with return to earth by way of an inclined entry into the earth's atmosphere was found to call for much higher accuracies in the initial flight path because of the relative thinness of the atmosphere. In all, the author of the paper, V. A. Yegorov, considered over 1,000 trajectories. He concluded that for close flight round the moon and for trajectories involving inclined re-entry into the atmosphere, some correction of the passive part of the trajectory by an auxiliary power unit was likely to be necessary. It would not be necessary for long range circlement or impact on the moon, provided the initial trajectories were close to parabolic.

The Rand studies also considered different types of flight path. One calculation showed that a rocket that encircles the moon and returns to earth may be 20 days later than expected. The precision required to return such a missile to the earth's surface, assuming no correction of orbit occurred after the initial launching period, would be about 10 times that required by the Vanguard rocket in putting an earth satellite into orbit. If the missile was to land within 1,000 miles of a chosen spot on the earth's surface, the initial velocity would have to be accurate to within 3 in per second.

To show the manner in which accuracy requirements vary for different types of rocket path, the graph on the next page was drawn up by R. E. Robertson in a paper, " General Guidance and Control Concepts for Satellites and Space Vehicles," read before the 1958 Congress of the International Astronautical Federation. It is only an approximate figure and many assumptions have been made in some of the curves: for example, that all the thrust is added impulsively near the earth without any further course correction. But it gives a good indication of the relative difficulty of guidance for several types of rocket mission. The improvement in guidance accuracy involved in the development of the earth satellite rocket from the V2 is shown, and it can be seen that a further improvement in angular accuracy of a similar order is required when progressing from the launching of earth satellites to the launching of probes that hit the moon. The difference in time scale for these two developments is worth reflecting on; so is the fact that the best accuracy reported for an ICBM is $\pm$ 30 miles. The greatly increased difficulty of circling the moon and returning to a braking ellipse both as regards misalignment and velocity error is also clear from the figure.

To put a probe in orbit around the moon requires the use of a retro-rocket, operated as the probe passes near the moon's surface. This was the intention of the United States Air Force in their attempt with Pioneer, and was the subject of another Rand study in which the initial velocity of the probe was envisaged as about 6·6 miles per second with the flight path passing within 1,000 miles of the moon's surface 2·12 days after take-off. As it approached the moon the probe would have a velocity of about 1·4 miles per second, which would have to be reduced abruptly to about half of this value if the probe was to go into an orbit around the moon.

Using Probes

Lunar probes explore the earth-moon system. They give information about the space between the two bodies as well as information about the moon itself. As far as our oldest satellite is concerned, knowledge about it is more detailed in some respects than in others. For example, the first identification of any element or compound on the moon was only made recently—the spectrum of molecular carbon vapour was observed by Dr. N. A. Kozyrev from what he described as a volcano on the moon. And on the other hand, the surface features of the moon

have been mapped with care and its topography has been extensively catalogued. Such a variation in extent of knowledge is to be expected in a science that until only recently has been completely observational. Now, as experimental techniques begin to enter into lunar studies, a more complete knowledge can be arrived at.

The origin of the moon, its composition, the mechanism that produced the craters, these have been topics of argument for many years. A definitive answer is to be expected from instrumented lunar probes. In turn the solution of these problems might shed light on the origin of the earth. But the important contributions of lunar probes might not appear in these expected areas of study. It may well be that the most important facts a probe will record are not anticipated.

The various types of investigation that are to be expected require different sorts of probe. For investigating the space between the earth and moon, satellites with elliptical trajectories passing close to each body in turn are the most valuable. For investigating the surface of the moon, probes that land would be better; and better still would be mobile probes moving across the lunar surface. For other experiments, probes that orbit continuously around the moon would provide the best means of obtaining information. Some of the possible experiments that might be made using these three techniques are described below.

At present, with the best telescope and conditions, it is possible to distinguish as a point an area on the moon about 100 yards in diameter, providing it contrasts well with its surroundings. Turbulence in the earth's atmosphere prevents the observation of finer detail. Amateur telescopes with apertures of about 12 in can observe craters of about 1 mile diameter.

Cislunar Space

Most probes could be used to provide information on the particles, radiation, and fields existing in the space between the earth and the moon. The measurements would be an extension of the investigations already carried out by earth satellites, and could also be considered as an investigation of the outer reaches of the sun's atmosphere. Already the US Pioneer probes that failed to reach the moon have yielded extremely valuable data on the two radiation belts encircling the earth and no doubt more will be obtained from the reports of Pioneer IV which passed within 38,000 miles of the moon on 4 March. This distance was too great to operate the camera triggering device included for test purposes, and also for obtaining information regarding radiation trapped in the moon's magnetic field.

The intensity of radiation, the distribution of ions at the outer fringes of the terrestrial atmosphere, and the extent of the magnetic field are quantities that have an important influence on atmospheric phenomena such as aurora, magnetic storms, etc., which in turn influence radio propagation. Further investigation of these and similar parameters will provide information necessary for any complete theory of the physics of the atmosphere. The most suitable probes will be those having long lifetimes and elongated orbits reaching out to or beyond the moon.

Gravitational Constants

The orbits taken up by probes passing near or hitting the moon will give information on the distribution of mass in the moon. A closer study could be made by a satellite circling the moon, in which case the variation of the orbit and the ultimate fall of the satellite on the lunar surface would give information on the lunar "bulge" and the lunar atmosphere.

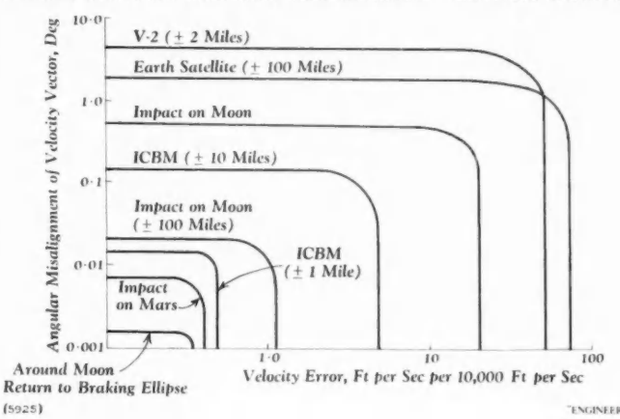
The lunar bulge is a matter of controversy. The main theory is that it was caused by the earth's gravitational field when the two bodies were much closer together: it is said to point towards the earth and to have a height of some 2,000 metres. However, there is considerable doubt as to the size and position of the bulge, and the perturbation of the orbit of a satellite passing close to the lunar surface would be a means of settling this doubt.

The lunar mass itself is not known to closer than 0·1 per cent, and a probe passing near to the moon, without circling it, would enable an improvement in the accuracy of this parameter. For measurements of this type, where the path followed by the probe must be known accurately, it is preferable for the satellite to be clearly visible so that it can be optically tracked. This may either be arranged by generating light in some way at the surface of the probe or by increasing its reflecting area, for example, by inflating a balloon with a strongly reflecting surface.

Lunar Atmosphere

It is generally agreed that if the moon has an atmosphere it is a very tenuous one. No light gases are expected but there may be traces of the heavy noble gases such as xenon and krypton. A probe incorporating a mass spectrometer similar to that carried by Sputnik III could give an indication of the gases present. In addition, a satellite in close orbit around the moon would reveal, by its retardation, the density of any lunar atmosphere.

A lunar ionosphere is to be expected and its presence may be of some importance. It is likely to be generated as a result of the ejection of photo-electrons by solar radiation, and it has been suggested that its density may be sufficient to interfere with radio communication and telemetry from the moon. Streams of charged particles from the sun may also give rise to a temporary ionosphere. Basically, to investigate the lunar ionosphere a variable-frequency transmitter is required to enable the absorption spectrum of the lunar ionosphere to be examined for various heights of the probe above the lunar surface.



The heavy flux of ultra-violet radiation and X-rays from the sun giving rise to the lunar ionosphere are prevented from reaching the earth's surface by our relatively dense atmosphere. The absence of such an atmosphere on the moon results in high radiation intensities at the surface and it has been suggested that this feature also accounts for the lack of colour on the moon.

The Lunar Surface

The absence of a thick atmosphere means that the lunar surface is subject to wide variations in temperature: from over 100° C in the lunar day to below −150° C during the lunar night. Such variations subject the moon's surface crust to alternating stresses that are likely, over the course of millions of years, to have broken up solid rock into rubble, stones, and dust. Measurement of the rate of temperature fall of the lunar surface during an eclipse shows that the surface is a good thermal insulator, the degree of insulation being compatible with that of a layer of dust deposited under vacuum conditions. Microwave measurements show that the temperature about a yard below the surface remains at a relatively constant value and suggest that the dust is at least a few feet thick. However, it will be necessary to land a probe on the moon's surface to discover the true thickness of the lunar dust coat.

One suggestion for such a probe is that it should televise close-up pictures of the lunar surface to earth. Alternatively, it is possible to envisage probes that measure various parameters on the moon's surface at different locations and depths; parameters such as electrical and thermal conductivity, impact resistance, radioactivity, etc. Eventually it may be feasible to scoop up a sample of the lunar surface and return it to a laboratory for analysis.

An important implication of this research into the composition of the moon lies in the fact that the earth and moon appear to have been formed at about the same time, and knowledge of the structure of the moon and its evolution should throw light on the structure and evolution of the earth. It has been suggested that more knowledge about the composition of the moon would prove to be of commercial value in providing an understanding of the occurrence of mineral deposits on earth. An interesting experiment will be the simple comparison of gamma activity in the lunar crust with that of the earth. This experiment could be carried out with a simple probe and would allow much to be learned about the probable constitution of the moon's crust.

The extent of the dust coat on the moon, whether it be measured in feet or furlongs thickness, will have considerable bearing on the origin of lunar craters. This topic has long been a point of dispute. The main theories offered have been that they are either of volcanic origin or that they are due to the impact of meteors. The variety of types of craters that can be observed suggests that there is room for both explanations but a definite conclusion cannot be reached until lunar probes reveal more information about the surface structure of the moon. A third theory that has been advanced recently is that the craters are caused by gas escaping from the interior into the rarified atmosphere. Experimenters have found that this occurance leaves circular craters of an observed type; it could also account for the apparent volcanic activity reported by Dr. Kozyrev.

Data About the Moon

Mean distance from earth, miles	$23{\cdot}9 \times 10^4$
Mean orbital velocity, miles per second	0·636
Sidereal period, days	27·32
Rotational period, days	27·32
Eccentricity of orbit	0·0549
Inclination of equator to orbit, deg.	6·678
Inclination of orbit to ecliptic, deg.	5·141
Mass, lb	$0{\cdot}162 \times 10^{24}$
Specific gravity	3·33
Mean diameter, miles	2,160
Acceleration due to gravity at surface, ft per sec per sec	5·33
Escape velocity at surfaces, miles per second	1·48
Satellite velocity at surface, miles per second	1·05

The Other Side

The fact that the period of rotation of the moon on its axis and the period of its orbit around the earth are so arranged that about 40 per cent of the moon remains hidden from terrestrial telescopes has inevitably lead to speculation as to the nature of the hidden side of the moon and to a desire to investigate it. Since so little is known of the other side of the moon, even the crudest pictures of it would be of value. Thus a very simple form of television system could be used in early satellites that pass around the moon. These satellites might make only one pass round the moon and then return

Continuing Lunar Journey

Data About the Earth, Venus, and Mars

	Venus	Earth	Mars
Mean distance from sun, miles	$67{\cdot}2\times10^6$	$92{\cdot}9\times10^6$	$141{\cdot}5\times10^6$
Mean orbital velocity, miles per sec	21·7	18·5	15·0
Sideral period, days	224·7	365·26	687·0
Rotational period, days	30 (?)	0·998	1·027
Eccentricity of orbit	0·00681	0·0167	0·0933
Inclination of equator to orbit, deg	—	23·45	25·17
Inclination of orbit to ecliptic, deg	3·395	0	1·85
Mass, lb	$10{\cdot}65\times10^{24}$	$13{\cdot}19\times10^{24}$	$1{\cdot}41\times10^{24}$
Specific gravity	5·06	5·52	4·12
Mean diameter, miles	7,610	7,918	4,220
Acceleration due to gravity at surface, ft per sec per sec	28·2	32·2	12·7
Escape velocity at surface, miles per sec	6·38	6·97	3·15
Satellite velocity at surface, miles per sec	4·51	4·93	2·23
Acceleration due to sun's gravity at planet's orbit, ft per sec per sec	0·0371	0·0194	0·0084

to earth, or could be in close orbit around the moon.

Lunar Magnetic Field

The extent of the earth's magnetic field and the distribution of a lunar magnetic field, if it exists, are quantities that can be investigated with lunar probes. Details of these fields would be of great value in helping towards an understanding of magnetic phenomena. The examination could be carried out by use of a magnetometer similar to that used in Sputnik III, or the field strengths near the moon could be calculated from data on the variation of cosmic ray cut-off with altitude. The latter type of experiment, however, is hampered by an absence of knowledge of the true value of cosmic radiation in free space and an uncertainty as to the cause of variations in the intensity observed from the earth's surface.

The intense radiation belts around the earth revealed by the US satellites and lunar probes suggest a way of detecting a lunar magnetic field. For the terrestrial radiation belts are considered as made up from particles that have approached the earth and become "trapped" in its magnetic field. A lunar magnetic field should trap particles in a similar matter and so should reveal its presence by a similar belt or belts of radiation.

Cosmic Ray Studies

Little is known about the lowest energies of cosmic radiation in free space. High altitude studies show that low energy cut-off of the radiation occurs at certain phases of solar activity, but it is felt by some that the absence of low energy particles is a local phenomenon and does not apply to the solar system as a whole.

Cosmic ray intensity is also known to suddenly decrease by about 10 per cent or more and to remain at such a value for several days. Various theories are put forward to account for this, some explaining it as a local phenomenon caused by screening, others claiming that it is a general phenomenon that would be observed at the same time in other parts of the solar system. The flight of cosmic ray counters in probes following elongated orbits beyond the moon could resolve these conflicting views.

Where Next

The curves in the graph show that the launching of a Martian probe is possible in the near future, and Venus might also be investigated soon. For this reason comparative data are given in the tables for not only the earth and moon but also for Mars and Venus. However, although there is not a large increase in accuracy required for simple inter-planetary journeys, a much increased reliability is required as the journeys take considerably longer.

Atomic Review

Fast Flux

WITHOUT breeding, it has many times been said, known deposits of uranium can only meet a substantial part of world energy requirements for a few decades. In the case of uranium, breeding can only be accomplished in a reactor operating on fast neutrons. Fast reactors are also said to be the best means of burning the plutonium bred in thermal reactors. It follows that fast reactors represent a major long-term development priority. However, since this development is likely to take a considerable time, it may be worth while to concentrate some effort at least on such technically difficult but theoretically promising systems as the molten-plutonium reactor, referred to in Atomic Review last week and the coupled fast-thermal reactor. The present state of fast reactor development is indicated in the following notes, which include information drawn from the recent twenty-fifth semi-annual report of the USAEC, *Atomic Industrial Progress and Second World Conference.* Next month the Dounreay fast reactor is due to begin operating, and last month the United States Transient Reactor Test Facility (TREAT), a pulsed reactor for testing fast reactor fuels under melt-out conditions, became critical.

World Fast Reactors Compared

The table below lists major fast reactors in in the United Kingdom, the United States and the Soviet Union. Critically assemblies and zero-energy experiments, such as the British ZEPHYR, reactors in the American ZPR series and the Russian BR-1 and 2 are omitted. BR-5 is to be a 5 MW thermal fast reactor with no electrical output to serve as a link between BR-2 and BN-50. The anticipated breeding ratios of BN-50 and BN-250 are given as 1·9, and the speed of coolant flow through the reactor as 6 and 9 metres per second respectively. The proposed shielding thickness is 60 cm in both.

Fast Reactor Background

Co-operation on fast reactor development between Britain and the United States has been extensive and to this end a formal agreement has been signed (see Atomic Review last 22 Aug.). The following observations are taken from a report by the United States *ad hoc* advisory committee on reactor policies and programmes, published early this year, which states that the co-operation between the United States and the United Kingdom on fast breeders has been very useful and should be continued and expanded.

While there is widespread agreement on the ultimate need for development of fast-breeder power reactors, there is not agreement on the required time scale for that development. . . . Information presented to the committee makes it appear prudent to press the development of fast breeder reactors on a schedule that would contemplate commercial competitive operation before the end of this century. . . . We do not believe that a crash effort on development of breeder reactors is warranted. We do note, however, that breeder reactors may lead to production of low-cost nuclear power at a date earlier than required from the standpoint of fuel resources. . . . In view of the ultimately necessary role of plutonium as fuel in fast breeder reactors, it is perhaps a weakness of the present programme that emphasis has been put on initial operation with uranium 235 as fuel. . . . It must be recognised that the achievement of economic breeding, and economic power utilising the bred plutonium, both depend critically upon the development of means for handling plutonium fuel elements at reasonable cost.

Coupled Fast-Thermal System

In theory, one region of a reactor operating on fast neutrons could be coupled with another region operating on thermal neutrons, with the result that the breeding gain would be characteristic of a fast breeder reactor and the prompt neutron lifetime would be characteristic of a thermal reactor. (A detailed description of a critical assembly employing this principle, ZPR-5, appeared in ENGINEERING, 29 March '57.) Results of recent critical experiments have indicated substantial agreement between theory and experiment. These data have given encouragement to the development of a fast reactor system with a reduced inventory of fuel and fertile material, increased specific power and irradiation level, and hence shorter doubling time and lower fuel-cycle cost. The United States *ad hoc* committee on reactor policies and programmes believe that this work should be pursued as part of the fast breeder programme.

Fast Liquid Fuel Systems

Reference to the molten plutonium fast reactor system appeared in Atomic Review last week, and a fused-salt fast breeder was discussed in Atomic Review on 27 Dec. '57. Another fast liquid system using uranium 235 and iron has also been proposed.

A study has been made of the nuclear be-

TABLE.—*Comparison of Fast-Neutron Reactor and Plant Characteristics EBR-2, EBR-1, EFFBR (Enrico Fermi), DFR (Dounreay) and the Projected Soviet BN-50 and BN-250 Plants*

—	EBR-2	EBR-1	EFFBR	DFR	BN-50	BN-250
General characteristics:						
Reactor thermal power, MW	62·5	1·4	300	~60	200	—
Gross electrical power, MW	16·5	0·2	100	15	50	250
Reactor coolant type	Na	NaK	Na	Na	Na	Na
Coolant temperature to reactors, °F (°C)	700 (371)	442 (228)	550 (288)	~390 (199)	—	—
Coolant temperature from reactor, °F (°C)	900 (482)	600 (316)	800 (427)	~650 (343)	896 (480)	1,004 (540)
Coolant flow rate through reactor, g.p.m.	8,200	292	30,400	~10,000	13,000	—
Feed-water temperature to steam generator, °F (°C)	550 (288)	446 (230)	400 (216)	—	—	—
Steam temperature, °F. (°C)	850 (354)	529 (276)	755 (402)	622 (328)	779 (415)	—
Steam pressure, lb per sq. in gauge (kg per sq. cm)	1,300	390	600	200	413 (29)	—
Steam flow rate, lb per hour	$0{\cdot}248\times10^6$	3,630	$1{\cdot}02\times10^6$	—	—	—
Reactor data: Core dimensions:						
Equivalent diameter, in (cm)	19·04	7·9	30·5	22	25·6 (65)	60·7 (107)
Height, in (cm)	14·22	8·5	31·2	21	25·6 (65)	60·7 (107)
Volume, litres	66·3	22·5	330	~178	—	—
Fuel alloy type	Fission	Uranium	U-Mo alloy	Uranium	—	—
Fuel alloy composition, wt. per cent:						
Uranium	95·0	100	90·0	100	—	—
Molybdenum	2·5	—	10·0	—	—	—
Enrichment, uranium 235, per cent	49	93·5	28	~40	—	—
Critical mass, uranium 235, kg	170	48·2	485	—	—	—
Specific power, kW per kg of total uranium	154	16·7	~149	—	—	—
Average heat flux, kcal per sq. m per hour	$1{\cdot}8\times10^6$	$5{\cdot}7\times10^5$	$1{\cdot}8\times10^6$	—	$1{\cdot}8\times10^6$	$2{\cdot}5\times10^6$
Max. neutron flux, n. per sq. cm per sec	$3{\cdot}7\times10^{15}$	—	—	—	9×10^{15}	$1{\cdot}3\times10^{16}$
Pumps, primary sodium loops: Pump type	d-c electro-magnetic	d-c electro-magnetic and centrifugal	centri-fugal	a-c linear induction	—	—
Capacity, g.p.m.	10,000	500	11,800	400	—	—
Head, lb per sq. in	75	25	110	16	—	—
No. of pumps	2	2	3	24	—	—
Pumps, secondary sodium loops: Pump type	a-c linear induction	centrifugal	centri-fugal	a-c linear induction	—	—
Capacity, g.p m	6,500	500	11,800	400	—	—
Head, lb per sq. in	65	30	22	16	—	—
No. of pumps	1	1	3	24	—	—

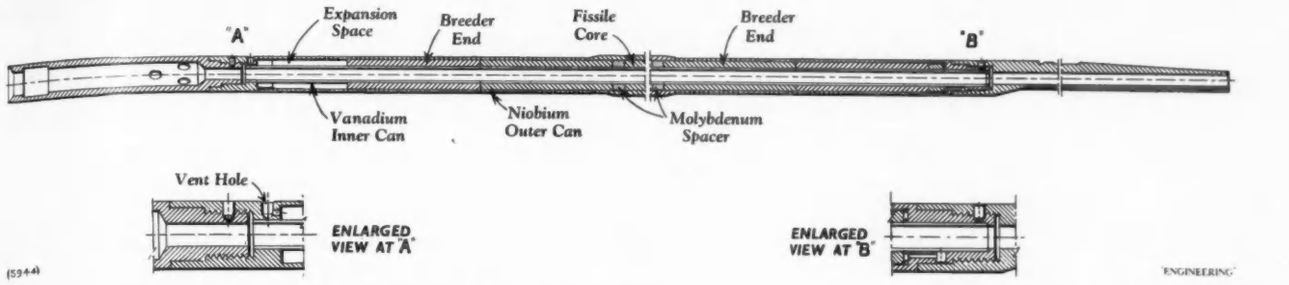


Fig. 2 Fuel element for the fast reactor experiment at Dounreay.

haviour of a fast reactor based on a liquid uranium iron fuel system, with particular emphasis on the region of low uranium 235 enrichment (10 to 20 per cent.). An enriched core and uranium 238 blanket system was briefly investigated also. The uranium-iron system was found to be operable from a nuclear standpoint but would present extremely difficult engineering problems because of the high temperatures involved. (W. E. Davis and others: Oak Ridge School of Reactor Technology, Tennessee, USA).

Fast Reactor Fuel Charging

Apart from safety, probably the most serious problem in the design of fast reactors is that of fuel charging and discharging. With so highly rated a reactor core, it would be extremely uneconomical to shut the reactor down while the fuel is changed; but the introduction of oxygen into the liquid-metal coolant, even in quantities of a few parts per million, would bring about a rapid deterioration of the niobium fuel cans, resulting in the release of fission products. Thus until some means of introducing fuel, without admitting air at the same time, is devised—possibly through a system of sodium locks with liquid-sodium flushing to reduce the oxygen concentration—a practicable power reactor based on the fast-fission system is unlikely to emerge.

To this end it will also be necessary to develop some means of continuously measuring the oxygen content of liquid metals at high temperatures. As far as is known, no such process has yet been discovered.

Fast Reactor Cross Sections

It has been said that cross-sections for fast neutrons are generally so low that from a nuclear standpoint almost any material might be used for canning the fuel of fast reactors. Thus in this case metallurgical considerations become paramount.

Dounreay Fast Reactor Tests

Writing in *The Scotsman* under the title "Dounreay Reactor Tests Begun," C. R. Tottle, deputy director of the Dounreay Experimental Reactor Establishment, recently reported that after initial tests on stability, the reactor power would be raised by increments.

At start-up experimental fuel elements containing more highly enriched fuel than the standard core will be used since these behave in a similar manner to the standard core operating at a higher power level. Examination of the elements after a reasonable period of irradiation will provide data for the decision to make each successive increase in power level. Experience with the American fast reactor EBR-1 shows that compact reactors of high heat rating can produce oscillations in power and neutron flux when neutron-absorbing materials or the control fuel elements are moved about within the core. The Dounreay fast reactor has been designed to provide stability under all conditions, though this feature has yet to be proved. Construction of a prototype reactor of 200 to 30 MW heat outputs (DFR will produce 60 MW heat) is anticipated during the next decade. The complexity of the Dounreay reactor is clear from Fig. 1.

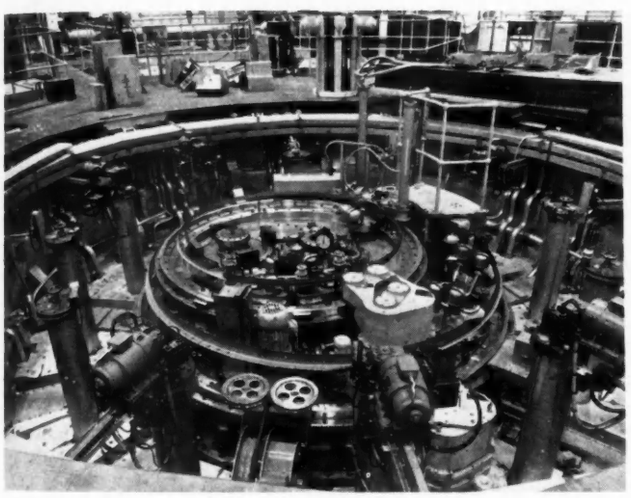


Fig. 1 (above) Upper face of the Dounreay fast breeder reactor.

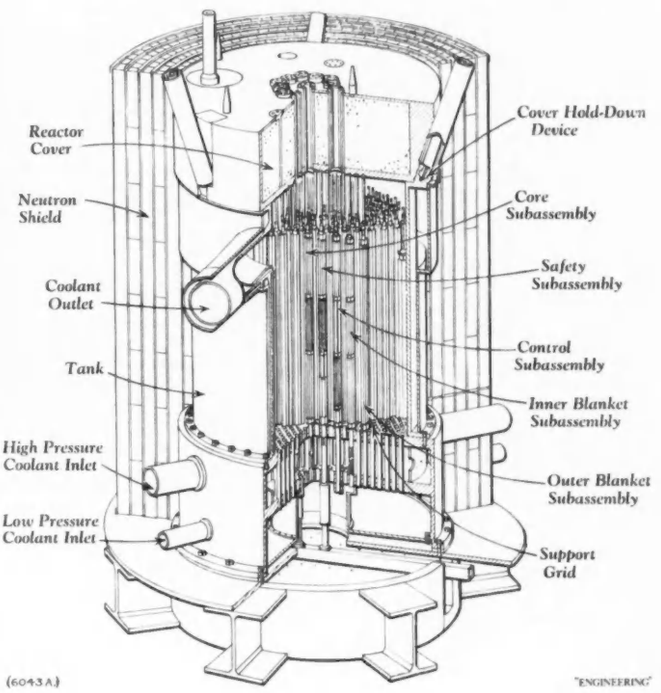


Fig. 3 (right) Cut-away view of Experimental Breeder Reactor 2, and (below) arrangement of the reactor core.

Dounreay Fuel Element

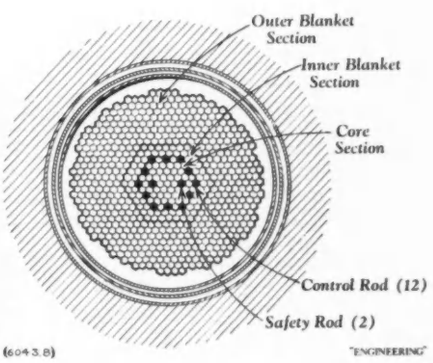
Fig. 2 shows the arrangement of the Dounreay fuel element, which is said to be unique in the method used to provide against the formation of a supercritical mass in the event of an accident causing a melt-out of the fuel elements.

The fuel is in the form of uranium tubes with an outer sheath of niobium and an inner sheath of vanadium. The principle of the design is that the inner (vanadium) sheath will melt with the uranium before the outer (niobium) sheath, allowing the molten uranium to escape from the core without contacting other elements and drain to the base of the core vessel which is shaped to give the molten uranium an unfavourable geometry from the criticality viewpoint. The niobium tube is capable of withstanding temperatures of 1,300° C in the presence of uranium for at least an hour, while the vanadium breaks down rapidly between 1,000° C and 1,100° C and alloys with the uranium which is near its melting point of 1,130° C. The molten uranium is thus expected to be discharged through the niobium tube without contact with the other elements.

United States Fast Reactors

Considerable work on fast reactors has been undertaken by the USAEC and the following is an outline of this work.

Early work on fast reactors was initiated in 1945 at Argonne National Laboratory and the Los Alamos Scientific Laboratory when both submitted proposals to the Manhattan Engineer District to design and construct fast reactors. The Los Alamos



Continuing Atomic Review

fast reactor, called *Clementine*, was primarily composed of plutonium rods cooled by mercury. No power was produced, and its breeding characteristics were not tested. It operated successfully as a research reactor until 1953, when it was dismantled. The proposal submitted by Argonne culminated in construction of the *Experimental Breeder Reactor No.* 1 at the National Reactor Testing Station, Idaho. It was designed primarily to study the physics and breeding characteristics of fast reactors, and secondly to study the technology of liquid metals as coolants. EBR-1 went critical in August, 1951. On 22 December, 1951, it produced the world's first electricity from atomic energy. Operation of EBR-1 on its first core from 1951 to 1954 demonstrated that breeding was feasible; a breeding ratio of 1 was achieved. Additional experiments were carried on with the second core until 29 November, 1955, when this core became overheated and partially melted down during a fast excursion experiment. EBR-1 went critical with its third core on 11 November, 1957. This core has been used for detailed studies of the effect upon the stability of the reactor of bowing of fuel elements. It is believed that excessive bowing of the fuel elements in the previous core caused the power excursion that disabled it. The third core was designed so that inward bowing of the fuel elements could be controlled and coolant flow altered as necessary.

The Experimental Breeder Reactor No. 2, like EBR-1, will be unmoderated and liquid-metal cooled. It will have a thermal output of 62·5 MW and an electrical capacity of 16·5 MW (given in other sources as 17·5 or 20 MW). EBR-2 will employ full-size components in its sodium system; for example, pumps and piping of 5,000 to 6,500 gallons per minute capacity. It is expected to yield much practical power operating information. Completion is expected by early 1960, and full power operation in the same year. EBR-2, which is shown in Fig. 3, was intended to be fuelled initially with uranium 235, and later with plutonium. The facility will include an integrated fuel processing and fabrication plant. Pyrometallurgical processing will be employed to remove only objectionable fission products from irradiated fuel elements, and to extract plutonium and objectionable fission products from the blanket elements. The resulting partially decontaminated fuel material will then be recast into fuel elements by remote control techniques. The fuel will remain in metallic form throughout, and the usual chemical processing will be avoided.

Los Alamos Molten Plutonium Reactor Experiment No. 1, which will use molten plutonium as a fuel, is a small-scale fast reactor, and is not designed to produce electricity. It will be employed as a short-term experiment primarily to develop methods of containing molten plutonium, which is highly active metallurgically. The containing material must be amenable to fabrication, inert to molten plutonium and the sodium-potassium coolant, and have a high melting point.

The Enrico Fermi Reactor Plant, shown in Fig. 4, is being constructed near Monroe, Michigan, by a group of electric utility and industrial companies forming the Power Reactor Development Company, to a design by Atomic Power Development Associates, and will supply steam for power production to the Detroit Edison Company. It will include a solid-fuel fast-breeder reactor. The design of this reactor provides for an initial output of 90 MW (electrical) and a possible later capacity of 140 MW. The breeding ratio is expected to be 1·12.

Fuel elements will be of an enriched uranium-molybdenum alloy clad with zirconium, and liquid sodium will be used in both primary and secondary circuits as the heat transfer material. The gas-tight reactor containment vessel is 120 ft high and 72 ft in diameter. Completion of the station is scheduled for late 1960.

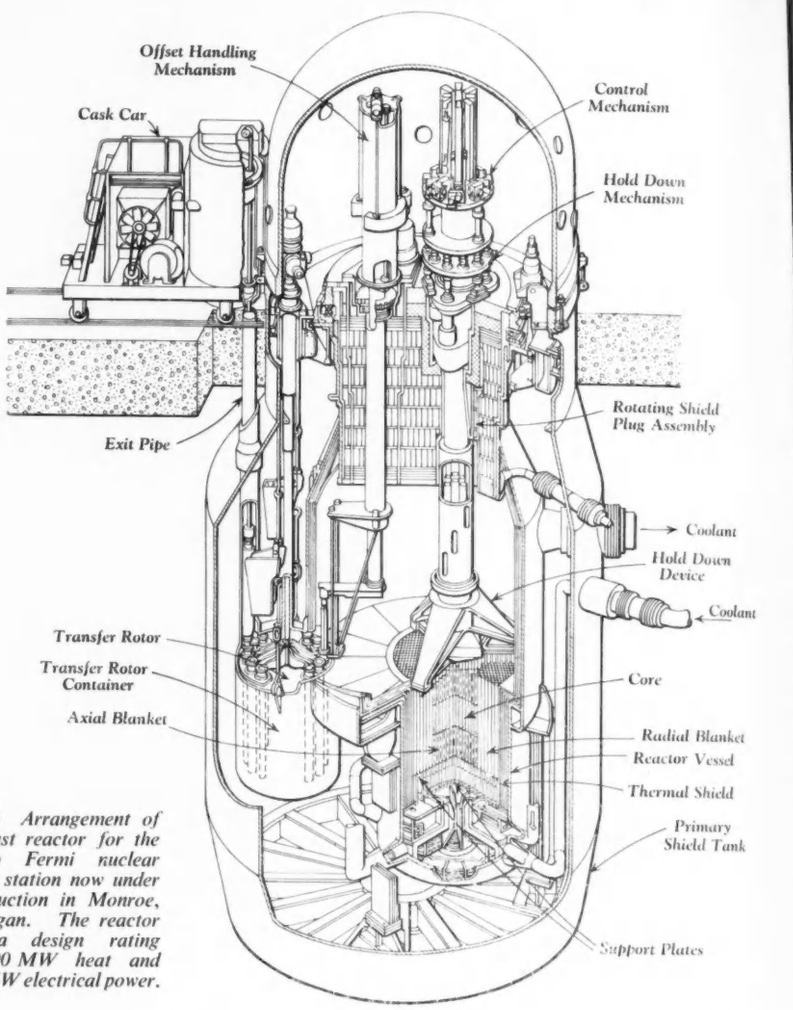


Fig. 4 Arrangement of the fast reactor for the Enrico Fermi nuclear power station now under construction in Monroe, Michigan. The reactor has a design rating of 300 MW heat and 100 MW electrical power.

Fast Reactor Hazards

Special attention has been given in the design of fast reactors to the minimising of potential hazards. EBR-2 may be taken as typical and characteristic features of the hazard considerations for this reactor have been listed in a Technical Progress Review, *Power Reactor Technology*, prepared for the USAEC by Dr. W. H. Zinn and associates of the General Nuclear Engineering Corporation.

(1) The operational instabilities which were exhibited in the past by the EBR-1 reactor have not as yet been completely explained. It is believed that these were, at least in part, due to mechanical instability in the reactor, notably bowing of the fuel elements. In EBR-2 every effort has been made to achieve a very rigid close-packed arrangement of the fuel and, in addition, to produce preferential bowing such as to effect a probable bowing coefficient which is essentially zero or negative. To the best of current knowledge, the reactor will have negative reactivity coefficients—prompt, slow, power and isothermal.

(2) The fast reactor differs from most thermal reactors in that the possibility of a very substantial increase of reactivity following a hypothetical fuel melt-down is difficult to disprove. The report states that, although there is no indication that fuel alloy melting would definitely result in a prompt critical assembly in EBR-2, pessimistic assumptions on a gravity-induced accident of this nature suggest the equivalent of 300 lb of TNT as a reasonable upper limit for the energy release. It is estimated that the primary containment system of the reactor would easily contain a nuclear accident equivalent to the detonation of 300 lb of TNT at the centre of the reactor.

(3) The chemical reaction between sodium and air would represent a relatively large energy release if a major fraction of the air in the containment building were to react. A rapid reaction of this kind could occur only if large masses of sodium in dispersed form were ejected from the reactor system into the air; this could presumably be caused only by a rather violent nuclear energy release. The secondary containment is estimated to be adequate to contain such a chemical reaction.

(4) Because of the very high power density which is characteristic of fast-reactor designs, the loss of coolant accident is one which must receive careful attention. Features of the EBR-2 design which minimise the probability of such a failure are: the pool type arrangement of the primary system makes the loss of coolant extremely improbable; either one of three pumps—two main pumps and one auxiliary—are sufficient for shutdown cooling; in the event of failure of all three pumps, the shutdown reactor will cool by natural convection; the large mass of sodium in the primary reactor tank has a very large heat capacity which prevents rapid temperature rise in the primary system; the heat will be dissipated from the primary system to the atmosphere by natural-convection shutdown coolers in the event of failure of the secondary coolant system.

References to Fast Reactors

References to fast reactors which have appeared in ENGINEERING are listed below.

Fast reactor projects tabled 7 Oct. '55, p. 498; Dounreay sphere 13 Jan. '56, p. 62; Los Alamos Molten Plutonium Reactor Experiment 13 April '56, p. 221. Pumps for liquid metals 27 April '56, p. 264, and Dounreay fast reactor model p. 283; Zeus 8 June '56 p. 474; Zephyr, Zeus and Dounreay fast reactors 3 Aug. '56, p. 158; Contracts for Dounreay 19 Oct. '56, p. 506; Plutonium core in Zephyr 16 Nov. '56, p. 635; Burnup of nuclear fuels 30 Nov. '56, p. 695, and Sodium coolant for fast reactors p. 700; Enrico Fermi reactor 14 Dec. '56, p. 762; Fast-thermal system 1 Feb. '57, p. 154; Fast breeder reactors 15 Feb. '57, p. 217; ZPR zero-energy reactors and Fast-thermal reactor 1 March '57, p. 281 and Fast reactor circulating system leak detector p. 282; Fast reactor fuel processing 8 March '57, p. 313; Dounreay fast reactor nearing completion 15 March '57, p. 345; Fast-thermal reactor at Harwell 22 March '57, p. 382; Fast-thermal reactor (ZPR-5) described in detail 29 March '57, p. 404, and Distinction between fast and thermal reactors 29 March '57, p. 413; Dounreay fast reactor vessel, ventilation and insulation 19 April '57, p. 509; Full-length articles on Dounreay project 17 May '57, p. 610, 24 May, p. 665, 7 June, p. 724; Zephyr and Zeus 23 Aug. '57, p. 253, and Pyrometallurgical separation for EBR-2 p. 255; Soviet fast reactor project 30 Aug. '57 p. 284; Heat transfer in fast reactors 6 Sept. '57, p. 314; Fission spectrum 6 Dec. '57, p. 726; Breeding 27 Dec. '57, p. 817, and Dounreay fast reactor, US fast reactor programme, fused-salt fast breeder p. 826; Judgment reserved on fast reactors 3 Jan. '58, p. 14; Dounreay reactor ready soon 14 Feb. '58, p. 206; Wire-cloth core fast breeder reactor and Flattening and conversion ratio for fast reactors 7 March '58, p. 303; Dounreay fast reactor critical in 1959 1 Aug. '58, p. 142; UK-USA fast reactor agreement 22 Aug. '58, p. 237; UK, US, USSR and French (Rapsodie) fast reactors listed 29 Aug. '59, p. 262, and Fast reactor safety instrumentation p. 274; Dounreay fast reactor delay and design problems 5 Sept. '58, p. 300; Oxide fuel fast reactor 31 Oct. '58, p. 571; Fast reactor projects compared 28 Nov. '58, p. 694; Features and housing of the Dounreay fast reactor and Fast reactors exclusively by 1980 5 Dec. '59, p. 734; Fast reactor fuel processing 19 Dec. '58, p. 792; Mercury-cooled fast breeder reactor 2 Jan. '59, p. 13; Enrico Fermi permit to build 9 Jan. '59, p. 47; Fast reactor fuels 30 Jan. '59, p. 136; Processing fuels for fast reactors 6 Feb. '59, p. 172; Molten plutonium reactor 6 March '59, p. 303.

Management

COMPANIES IN THE COMMONWEALTH

With so much talk of the Free Trade Area and Common Market of Western Europe, it would be easy to forget that some notable British engineering firms have established themselves firmly in the Commonwealth. By so doing they are actively helping to create a pattern of working partnerships—among advanced and underdeveloped countries—which will go far to reduce the buffetings of international politics. The United Kingdom has a stake in the Commonwealth and, apart from purely commercial considerations, can contribute to the development of those countries, with the satisfaction of participating in new growths throughout the world. This is the sixth of a number of articles in which the present position and prospects of British engineering firms in the Commonwealth are examined. The previous five, published on 15 August, 1958, 19 December, 1958, 16 January, 1959, 13 February, 1959, and 27 February, considered Hawker Siddeley; Oldham and Son Limited; Ruston and Hornsby Limited; Vickers Limited; and Crompton Parkinson Limited.

6 — Head, Wrightson and Co. Ltd.

Two previous articles in this series (on Hawker-Siddeley and Vickers) have dealt with two giants. The activities of Head, Wrightson, whose issued capital is £2,241,005 and who still retain some of the characteristics of a family business, are on a different scale, though they are leaders in their particular branches of engineering and have more than doubled their trading profits over the last seven years. One reason for choosing them for this series is that they are typical of a large number of medium-sized companies in specialised branches of the British engineering industry; and another is that, although their present production facilities in the Commonwealth are on a modest scale, they are likely to expand considerably during the next decade.

Head, Wrightson are, to a considerable extent, selling "know-how" and experience, and the general trend is for this important activity to be accompanied by an increasing degree of local manufacture of parts and equipment which do not have to be made in England. About 40 per cent of their output is for export and their early entry into the nuclear power plant field is likely, in due course, to lead both to a rise in this percentage and to a rise in the amount of fabrication work which is done overseas.

The firm have followed two lines in the nuclear power field: they are participants (along with Parsons, Reyrolle, Parolle Electrical, Sir Robert McAlpine, Alexander Findlay, Clarke Chapman, Whessoe and Strachan and Henshaw) in The Nuclear Power Plant Company Limited of Newcastle upon Tyne, who, although they are likely to be kept busy for some time with their Bradwell-on-Sea contract, are also actively seeking overseas orders and are likely to get them. Head, Wrightson are mainly concerned with the manufacture of heat exchangers, so far as the work of the Nuclear Power Plant Company is concerned, though they are also responsible for certain ancillaries at Bradwell and for laying the graphite shielding within the reactor shell. They have also struck out on their own and have been awarded contracts for a £2 million "Pluto"-type heavy-water research reactor for Denmark and for a £2 million "Dido"-type heavy-water research reactor for Germany. The latter, which will be paid for by the Land Nordrhein-Westfalen, will be placed at the disposal of the universities of Aachen, Bonn, Cologne and Munster. Apart from their earlier contracts for Harwell, on which they cut their teeth, they have supplied a similar reactor to the Australian Atomic Energy Commission at Lucas Heights, Sydney.

Head, Wrightson's existing production facilities in the Commonwealth are on a comparatively modest scale, through two associated companies, Wright Boag and Head Wrightson (Pty.) Limited at Benoni in the Transvaal who do mining, mechanical and constructional engineering and make special iron castings; and Gibson Battle and Company Limited at Sydney, N.S.W., who do general engineering and merchanting. Head, Wrightson also have their own companies in Johannesburg and Sydney which, however, only do consulting and merchanting business and do not manufacture. These are Head Wrightson and Company South Africa (Pty.) Limited and Head Wrightson (Australia) Pty. Limited. In his speech at the last annual general meeting the chairman, Mr. Richard Miles (who is a brother of Mr. John Miles of the well known steelworks consultants, John Miles and Partners), said that they were still finding conditions in Canada difficult and, certainly, the company does not seem to have obtained any important contracts there. He also indicated that the difficulties encountered by the mining industry in South Africa in raising capital overseas might reduce the company's orders for capital equipment and that they were giving attention to other local needs. In 1956 they obtained a big order from Iscor for an electrostatic gas cleaning plant.

A large part of the turnover of the group is, of course, derived from the design, manufacture and erection of blast furnace and steelworks plant, oil refinery plant, dock and harbour equipment, bridges, etc. Since the recent structural reorganisation of the Group the manufacturing side of this work is handled by Head Wrightson Teesdale Limited, of Thornaby, where the company's nuclear power plant production work is also carried out, though design and contracting is done by the Nuclear Power Division of the parent company at Yarm-on-Tees. Consulting, design and contracting for iron and steel works is now in the hands of Head Wrightson Iron and Steel Works Engineering Limited, of Thornaby.

Among recent big overseas steel works orders on which the company have been engaged are the Indian National Steelworks at Durgapur and the Spanish National Steelworks which was completed in the autumn of 1957. Both were undertaken by consortia of which Head, Wrightson are members. Head, Wrightson's share of the "Ensidesa" (Empresa Nacional Siderurgica S.A.) contract at Aviles was over £4 million but in addition they were responsible for about £2 million worth of work supplied from Spain—an indication of the way in which work of this type involves large scale contracting more like, say, dam building, than local factory production. To be successful it also involves training of local nationals as operators of the plant and Head, Wrightson were well placed to arrange this in England, for example, at Consett Iron Company, Park Gate Iron and Steel Company and John Summers Limited.

Head, Wrightson's share of the Durgapur contract was about £11 million out of a total of £80 million. The other principal members of the Indian Steelworks Construction Company Limited were Simon-Carves Limited (coke ovens), Wellman Smith Owen Engineering Corporation Limited (melting shop) and Davy and United Engineering Company Limited (rolling mills). The consortium also included a group of structural steel manufacturers and a separate group of leading electrical engineering companies was formed to undertake the electrical work.

The civil engineering was carried out by the Cementation Company Limited. The sterling expenditure involved was met by a £15 million loan from the British Government, £25 million from Indian sterling balances and £11·5 million from credit facilities provided by a group of British banks. Head, Wrightson's work included the design and manufacture of three blast furnaces together with gas cleaning and complete ore preparation plant. The company generally have to face strong international competition for contracts of this kind, particularly since a country such as India tends to distribute the work, partly perhaps in order to keep a balance between East and West and between different Western countries and avoid what they regard as excessive dependence on any one. For example, the Russians got the contract for the new steel works at Bhilai (total cost around £85·5 million) and the Germans (Krupp, Demag and others) got the contract for the Rourkela steelworks. It should be added that Mr. T. T. Krishnamachari, until recently Minister of Finance, said that this was more by accident than design.

One of Head, Wrightson's principal competitors in the design and erection of blast furnaces and steelworks are their neighbours at Stockton-on-Tees, Ashmore Benson Pease and Company Limited, a subsidiary of the Power Gas Corporation. This company, for example, who have carried out extensive work in South Africa and India, obtained in August 1956 a contract for a new 29 ft hearth diameter blast furnace at the Port Kembla works of Australian Iron and Steel, which is controlled by Broken Hill Proprietary Limited. The total contract value was £A9 million. Power Gas include among their overseas subsidiaries The Power-Gas Corporation (Australasia) Pty. Limited of Melbourne, Ashmore Benson Pease and Company Africa (Pty.) Limited of Johannesburg, and Power-Gas Canada Limited of Montreal. In addition they have Power-Gas France SARL which should give them a strong start in the European Common Market. Their total range of interests differs somewhat from Head, Wrightson's in that apart from their iron and steel works activities they are very active in the chemical plant field and, through Rose Downs and Thompson Limited, in vegetable and fish oil extraction.

The Head Wrightson Machine Company Limited, of Middlesbrough, is an important producer of heavy equipment for working, processing and coating steel and non-ferrous bar, tube, sheet, strip and plate. Examples are mills, billet shears, bar reeling machines, triple-draw drawbenches, uncoilers for strip, heavy plate levellers, etc. This type of heavy plant is unlikely to be manufactured overseas at any rate for some years ahead. In their range of machinery for tube manufacture for example, Head, Wrightson are competing with companies such as Brookes (Oldbury) Limited, W. H. A. Robertson and Company, Limited, of Bedford, and Edgar Allen and Company Limited, though in steelworks plant generally there is, of course, a much wider range of manufacturers.

Head Wrightson Processes Limited are very active as consultants and contractors in the petro-

Design

SKIP WINDING PLANT AT RUFFORD COLLIERY

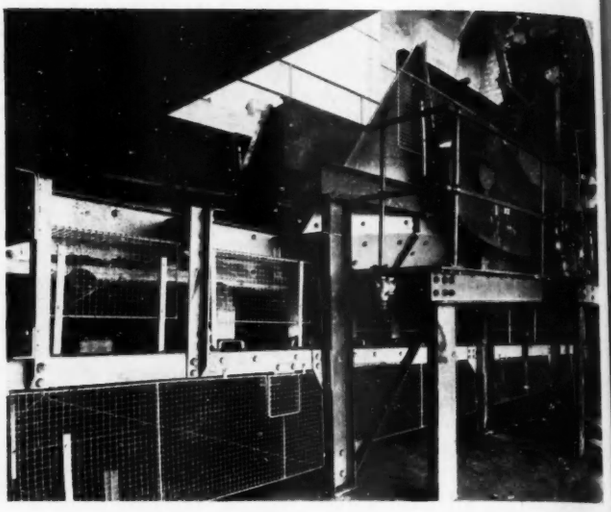
THE surface and underground equipment for the Rufford Colliery reorganisation is designed to handle 520 tons per hour of run of mine coal using mine cars of 4 tons capacity and bottom discharge skips with a capacity of 12 tons each together with the Koepe winder towers. The equipment was supplied by Head Wrightson Stockton Forge Limited, a subsidiary of Head, Wrightson and Company Limited. The Koepe towers are shown in the final stages of construction. The guide tower and air casing are of steel construction and are provided with internal platforms and airlock access doors. Fixed spear guides are fitted extending from below the skip discharge point to the top of the guide tower. Hydraulic buffer cylinders, with 9 in bore and arranged two for each skip at the top of the guide tower, arrest the rising skip in the case of an overwind. As an additional safety measure a Bennett safety catch gear is provided in the top section of the tower to hold the skip should the rope break during an overwind. The catches are designed for a static load of 37 tons falling 10 in on to four catches.

Koepe winder tower at Rufford Colliery.

The bottom discharge skips incorporate an anti-breakage device fitted with a guillotine-type bottom discharge door which is pneumatically operated when the skip reaches the discharge position. Men and materials can be carried by the skips each of which is approximately 4 ft 4 in wide by 13 ft by 32 ft long.

The receiving hopper has a capacity of approximately 36 tons. It is totally enclosed and provided with pneumatically operated doors at the top and bottom, interlocked to form an airlock for the passage of coal from the upcast shaft to atmosphere. As the skip arrives in the discharge position it contacts an in-line gear and valve, which operates the pneumatic cylinders opening the discharge door on the skip and the top door on the receiving hopper, provided the bottom guillotine door on the receiving hopper is closed. When the skip leaves the discharge position the action is reversed so that the coal can pass on to the apron feeder.

The 54 in wide apron feeder with an articulated steel apron, carried on 6 in pitch roller chains operating on driving and trailings prockets, has apron chains carried on the top by steel channel tracks and on the underside by cast-iron rollers spaced at intervals. The material is retained on the apron by steel skirts and the drive is from a 10 h.p. 720 r.p.m. electric motor through a reduction gearbox and a chain drive to the headshaft. The speed of the apron plate is approximately 50 ft per minute.



The apron feeder.

Men and materials winding is carried out from the shaft collar level and hand-operated hinged platforms and sliding gates are provided. Skip changing is also done from this level and to facilitate these operations a crawl beam and special skip bogie are provided.

The multi-rope suspension gears are of the four-strand type and each strand has a minimum factor of safety of 10, in relation to the maximum static load of 12·5 tons per rope end; 50 tons per four ropes. Each strand incorporates a load capsule and gauge so that loads on each rope can be checked. Individual components have been proof tested to not less than 2·5 times their proportion of static load. The balance rope suspension gear is of the swivel type; two ropes are attached to the underside of each skip.

The compressed air for the whole of the skip surface pneumatic equipment is obtained from two 75 h.p. twin-cylinder two-stage self-contained water cooled compressors, each running at a speed of 475 r.p.m. with a free air delivery of 358 cu. ft per minute at 100 lb per sq. in.

All the controls for the surface equipment are grouped on one panel situated in the control house in the Heapstead building at skip discharge level. The plant is arranged for automatic winding, but an over-riding control allows manual operation if and when required.

Qualter Hall and Company Limited supplied the skips and skip door operating equipment, and Holman Brothers Limited the compressors for the project. Messrs. Young and Purves, consulting engineers, designed the tower.

Continuing Head, Wrightson and Co. Ltd.

leum refinery and chemical plant field. Among processes for which they have recently signed licence agreements are the Inventa processes for the production of methanol and formaldehyde. The licensors are Inventa A.G. of Lucerne and the agreement covers the United Kingdom and the Commonwealth excluding Canada. They also licence their products for manufacture abroad: for example, not long ago they licensed D. Bonaldi to manufacture their air-cooled heat exchangers in Italy. Here again this type of activity is likely to lead to considerable expansion of business in the Commonwealth though not so much to manufacture overseas. The petroleum refinery and petrochemical engineering business has, of course, fallen off a lot lately and shows no signs of reviving. In this field Head Wrightson Processes are well known for their heat exchangers, oil/gas separators, tubestills, etc. They also make drinking water plants, diesel engine silencers and induced and natural draught cooling towers, for all of which the outlook appears at present to be rather more favourable.

Other subsidiary companies at Thornaby, Stockton-on-Tees, Eaglescliffe, and Seaton Carew are important manufacturers of steel and iron castings and drop forgings. In all these fields the group have considerable specialised experience which might later be used to establish manufacturing facilities overseas, though this has not yet been done.

Mention should be made of Head Wrightson Colliery Engineering Limited, of Thornaby and Sheffield, who carry out consulting, designing and contracting work on coal preparation and ore dressing plant. This company had its origin in Colliery Engineering Limited, of Sheffield, which Head, Wrightson acquired in 1955 from the British Metal Corporation. A small subsidiary, the Cupola Mining and Milling Company Limited, is engaged in the production of heavy-media minerals for coal preparation plants.

Head Wrightson Aluminium Limited carry out consulting and contracting work for light alloy structures such as bascule bridges, crane and dragline jibs and large hangar doors. In this field they compete with companies such as Structural and Mechanical Developments Limited in the Hawker Siddeley Group.

Broadly the picture is of a flourishing and energetic medium-sized group at home which has made a small start in developing production facilities in two Commonwealth countries but has carried out extensive construction and contracting work in several others. It has been active in getting quickly into new fields, especially atomic energy, and a number of these have a big potential market in the Commonwealth. Its range of products is reasonably widely spread and though some, such as petroleum refinery plant, may be passing through a difficult time, the group as a whole should have no difficulties over orders—indeed the orders on hand are believed to be very large. Gradual expansion of the footholds established in the Commonwealth seems likely to take place.

BEARINGS WITH RACES MADE OF WIRE

Wire race ball bearings have been successfully used for many years in mechanical engineering, and have been continuously developed and improved. More recently, wire-race roller bearings, as well as wire-race combined ball and roller bearings, have been perfected, so that it is now possible to refer to these types collectively as anti-friction bearings. These developments offer new prospects that certain problems of bearing construction which have hitherto been solved by unsatisfactory methods, are now capable—even in complex layouts—of a remarkably simple and effective solution, by the application of wire-race anti-friction bearings. The following account is an abridged version of an article by Herr B. Braun, Dipl. Ing., which appeared in "Technische Rundschau" Switzerland, No. 18, 1957.

WIRE-RACE anti-friction bearings are low friction bearings, whose races consist of high-grade spring steel wires located in suitably shaped recesses in the bearing rings, as shown in Figs. 1 and 2 below. The ends of the wire rings remain open, a gap of 0·02 to 0·08 in being left to ensure that the wire rings make good contact, and are able to expand if, for instance, changes in temperature occur. This gap does not impair the load carrying capacity of the bearing, since the number of rolling elements is large, nor is it in any way noticeable in the running performance of the bearing.

The steel wire inserts are provided with special

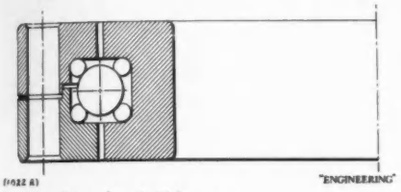


Fig. 1 Wire-race ball bearing.

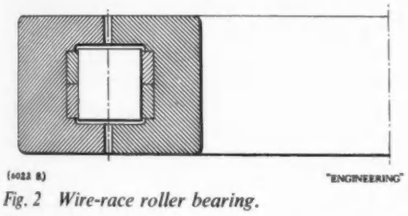


Fig. 2 Wire-race roller bearing.

running surfaces to carry the rolling elements. These race surfaces are produced in the smaller sizes, by rolling in only; and in the larger sizes by rough grinding followed by rolling in. To enable the rolling-in process to be carried out, and to permit adjustment of the wire-races, wire-race anti-friction bearings are nearly all provided with adjusting devices. In the case of combined ball and roller wire-race bearing, it is important that the rows of balls and rollers should be capable of independent adjustment as far as possible, so that balls and rollers can be proportionately loaded.

The enclosing bearing rings of wire-race anti-friction bearings, since they are left unhardened and are readily machineable, can be drilled or tapped for fixing purposes. In addition, the rings may have gear teeth cut in them direct, a form of construction which has the advantages of lower cost and greater compactness when compared with a separately fitted toothed ring. In principle, the bearing rings can be made in many different materials.

In a wire-race ball bearing, the rolling-in process results in an equal curvature of ball and race, so that the contact between ball and race in an unloaded bearing is not a single point, as in normal ball bearings, but a line contact, as in roller bearings. As is well known, the load carrying capacity of bearings under line contact conditions is greater than under point contact conditions, other circumstances being equal. Added to this is the fact that in most forms of wire-race ball bearings the balls are in contact with the race at four places, whereas in the ordinary ball bearing there are only two places of contact between ball and race.

The race wires are inserted in recesses in the bearing rings. The main factor governing the true running of the bearing is the accuracy of these recesses or wire seatings. The wire seatings can be formed to very high standards of accuracy, since they are left unhardened and are therefore not subjected in any way to subsequent changes of shape. As far as any residual inaccuracies are concerned the bearing is largely self-compensating. Rotational errors in a wire-race anti-friction bearing amount to approximately one-half to one quarter of the eccentricity in the wire seatings.

Any inconsistencies in the gauge of the race wires are unable to affect the accuracy of the bearing, since all variations in thickness are equalised during the process of rolling-in the wires. Owing to their construction wire-race anti-friction bearings—even those with large diameters—can be adjusted to give any desired amount of play. It is equally possible to adjust a bearing to give zero play, or pre-load.

The backing rings of wire-race anti-friction bearings can be of the split type. Wire-race bearings of this type can be used in the same manner as ordinary split plain bearings. Admittedly, the load carrying capacity of the bearing is lowered by splitting the backing rings. However, this type of construction does make it possible to use anti-friction bearings for applications where hitherto it has only been possible to fit plain bearings.

The fact that the races are fitted as separate items independent of the backing rings permits the low-cost replacement of damaged or unserviceable race wires by new ones. It is possible to construct wire-race anti-friction bearings with diameters up to 13 ft (and in exceptional cases even larger). On the other hand, wire-race anti-friction bearings are widely used in the optical industry and as precision bearings having diameters of only a few inches. Even in large diameter bearings, relative rotational speeds of the bearing rings as high as 80 ft per sec are permissible.

Wire-race bearings offer the designer opportunities of planning the layout of a machine on completely new principles. Any special requirements in regard to the construction and load carrying capacity of such a bearing—for example, large diameter, split construction, ability to take special types of load, particularly tilting loads, and moments to be resisted—can be readily catered for by the wire-race anti-friction bearing.

In the field of mechanical engineering the hitherto common practice of mounting turntables and faceplates in plain bearings is giving way before the obvious advantages of anti-friction bearings. This is particularly true of the field of machine tool building where the present trend is towards ever higher speeds and improved accuracy. In the latest and most successful faceplate mounting arrangements using anti-friction bearings, there is a steadily growing tendency towards shortening the centre post and increasing its diameter. This accounts for the increasing use in such applications of a single large bearing capable of taking forces applied from any direction. In the bearing layout shown in Fig. 3 (faceplate diameter approximately 8 ft) the length of the centre post has in effect been shortened to no more than the height of the bearing, whilst its diameter has increased to that of the bearing. This type of bearing layout has therefore virtually ceased to have a centre post; in design and function it is well matched to the turntable and faceplate and in addition it offers the maximum degree of stability, compactness and economy.

Turntables and faceplates equipped with wire-race anti-friction bearings achieve accuracies of the order of 0·0004 in maximum radial and axial run-out over face. For certain applications these errors can be still further reduced. With 80 ft per sec as the maximum allowable relative peripheral speed of the bearing rings, practically

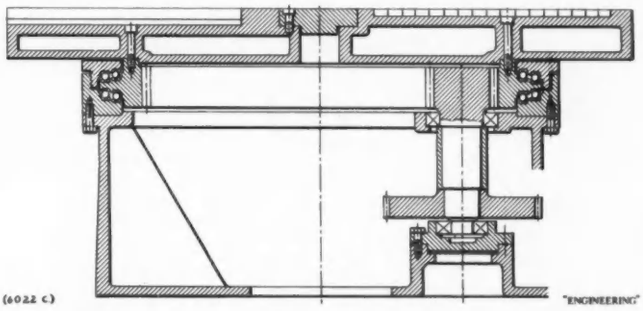


Fig. 3 Faceplate equipped with wire-race ball bearing

all ranges of turntable and faceplate speed can be dealt with. From the economic viewpoint there are important advantages in using wire-race anti-friction bearings to support turntables and faceplates. In general the overall construction is cheaper than the use of a centre post plus plain bearings or ordinary anti-friction bearings.

Wire-race anti-friction bearings are used nowadays to support large radar reflectors and aerial antennae. These equipments, which continually make rotary or oscillatory movements at moderate speeds, impose a thrust load on the bearing due to the dead-weight of the moving system coupled with considerable journal loading and tilting forces which act on the bearing due to the substantial wind pressures encountered. Bearings for this kind of duty must be absolutely free from play so that the unit turns smoothly and without vibration even under the heaviest wind pressure. Similarly, wire-race anti-friction bearings are used in optical and astronomical equipment such as reflecting telescopes, for example, with excellent results. Here, too, there is an outstanding need for a bearing offering zero play combined with minimal limits of radial and angular runout. Even in the large-diameter versions these requirements can be met with certainty and without difficulty.

In this connection it may be of interest to

Continuing **Design**

note that the wire-race anti-friction bearing was developed in the optical industry.

In the last war tens of thousands of wire-race ball bearings were used in a great variety of equipment and gave excellent performance. Bomb release gear, guns and optical equipment all made use of wire-race ball bearings. In addition, wire-race ball bearings were used in large numbers for such applications as combined height/rangefinder/predictor units, fire-control equipment, gun carriages, submarine periscopes and direction-finding periscopes for marine and aircraft purposes.

BEARING SEALS

In nearly all military equipment there is a great need to achieve compactness and light weight. To realise these aims the bearings employed must generally speaking be closely matched, both in construction and load carrying capacity, to the applications concerned. For many types of duty the main requirement is for large diameter bearings. Bearings of this kind offer big technical advantages when built in the form of wire-race bearings.

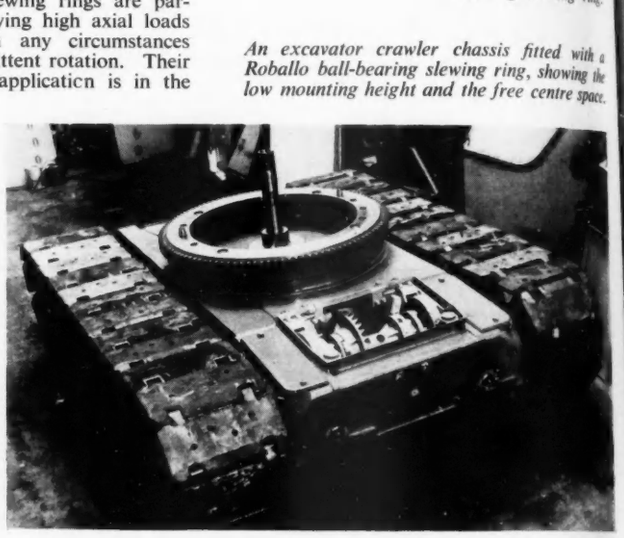
In chemical engineering wire-race anti-friction bearings in a great range of types are used very successfully in rotary furnaces and kilns, revolving drums, mixer tanks, revolving hoppers, rotary screens, feeder worms and similar equipment. The wire-race bearings used in this kind of plant often have to operate at high temperatures (250° C and above). Careful sealing arrangements built into the bearings themselves are provided to exclude dirt and moisture from the races. The foodstuffs industry uses wire-race anti-friction bearings for turntables, kneading drums, mixing drums, grinding mills of all kinds, and similar equipment. Bearings exposed to corrosive media are made of suitably corrosion-resistant materials. Further applications, to name but a few, include machines for laying up cables, machines for bark removal in the woodworking industry, screwcutting machines, jolt-squeeze machines, charging bells on blast furnaces, X-ray equipment, etc.

BALL-BEARING SLEWING RINGS

Ball-bearing slewing rings based on principles described in the preceding article are made by Steels' Engineering Products Limited, Sunderland, and are marketed exclusively by their associate, the Roballo Engineering Company Limited, 43 Dover Street, London, W1. They are made in two types—one with a single row of balls and two ring components; the other with a double row of balls and three ring components. The former is mainly intended for taking up radial loads and axial loads up to about 10 tons combined with small tilting moments. The main feature of the double-row designs is the " collar " ring. This arrangement absorbs high axial and radial loads and very large moments.

Roballo ball-bearing slewing rings are particularly suitable for carrying high axial loads and tilting moments in any circumstances calling for slow or intermittent rotation. Their most important field of application is in the design of cranes and excavators of all types. The slewing rings can be installed with low mounting height, a useful feature for mobile equipments requiring a low overall height, or for rail-mounted equipments whose dimensions are restricted by a loading gauge. The ability of the Roballo slewing ring to carry a high tilting moment on a small diameter is particularly useful where space is restricted (e.g. a stockyard or a ship's deck), or where a heavy counterweight or a large tail-swing is inadmissible.

Exploded view of ball-bearing slewing ring.



An excavator crawler chassis fitted with a Roballo ball-bearing slewing ring, showing the low mounting height and the free centre space.

Three New British Standards

SPLIT COTTER-PINS

An important step towards international standardisation of practice has been taken in the recently revised British Standard for Split Cotter Pins, BS1574:1958.

In common with American and Continental standards, the new standard now defines the nominal length of the pin as the distance from the underside of the eye to the extreme end of the short leg. The sizes of mild steel cotter pins in diameters from $\frac{1}{32}$ in to $\frac{1}{2}$ in listed as standard are now based on this principle and users should bear this in mind when ordering supplies to the new standard.

Work on the standardisation of split cotter pins is also proceeding in a committee of the International Organisation for Standardisation; and in preparing this revision of BS1574 the opportunity has been taken to include an appendix giving the metric sizes likely to be included in an ISO recommendation together with their nearest British Standard equivalents.

Copies may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W1 (4*s*).

PLASTICS SCALES FOR ARCHITECTS, ENGINEERS AND SURVEYORS

A new 24 page publication, BS 1347 : Part 2 : 1959, *Architects, Engineers' and Surveyors' Scales*, Part 2: *Plastics Scales* issued by the British Standards Institution specifies requirements for white opaque plastics scales of either oval or flat section. The scales are required to bear the mark " BS 1347."

Data on scale reference numbers, designation, sub-divisions, figuring, etc., are provided in tables which deal separately with the following scales: foot and fractional foot, foot and decimal foot, decimal inch, combined fractional and decimal, combined inch and metric, aircraft engineers', land surveyors', quantity surveyors', ordnance, combined ordnance and fractional, metric and English equivalent, drafting machine (foot and fractional foot), drafting machine (inch and fractional inch), and drafting machine (metric and fractional inch).

Copies of the standard may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W1 (6*s*).

REFRIGERATED DISPLAY CABINETS

Several large food manufacturing organisations as well as refrigeration equipment manufacturers were among those interested in the preparation of the first British Standard for open and closed refrigerated display cabinets, designated BS 3053: 1958.

A 23 page publication, it deals with the materials and performance of the cabinets in relation to an average temperature within the cabinet of 0° F (with a maximum of + 5° F at any point) above which the temperature of the food in a fully loaded cabinet should not rise.

Most of the materials are required to be of British Standard quality, for example, the corrosion resistance of the electro-plating is governed by compliance with BS 1224, and electric cables and cords must likewise comply with the relevant British Standard. Again, cabinets must not interfere with radio or television reception—a requirement governed by BS 800, " Limits of Radio Interference."

Performance.—There are specified production tests relating to pressure, insulation resistance, earth continuity and the ability of electric circuits to withstand specific high-voltage.

Refrigerated display cabinets manufactured in accordance with this specification will bear the British Standard number BS 3035.

Copies may be obtained from the British Standards Institution, Sales Branch, 2 Park Street, London, W1 (6*s*).

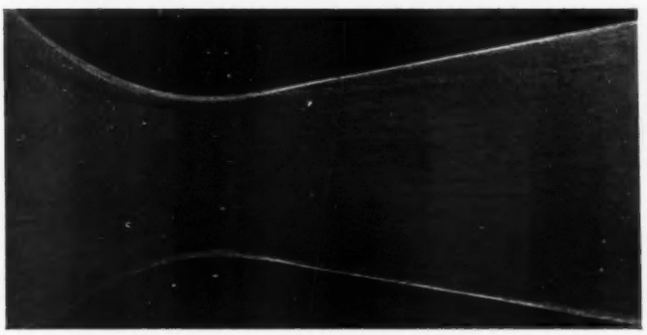
Research and Development

MIXED LOADS SUPPLIED FROM ONE COMPRESSOR

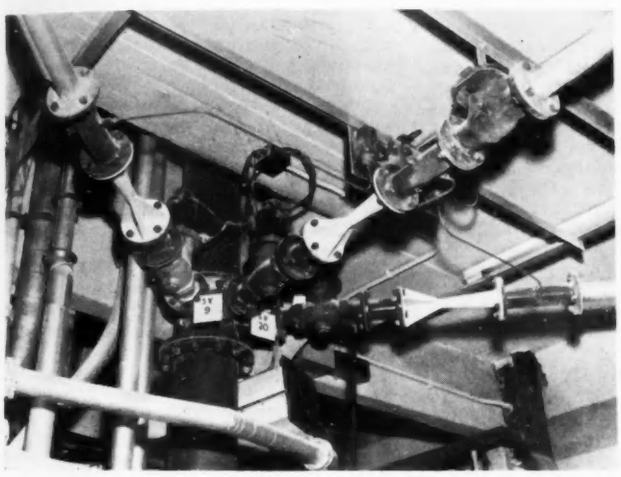
Mach-One Valve Simplifies Pneumatic Conveyor Systems

At their research laboratories at Stockport, Cheshire, the Simon Engineering Group have developed a sonic valve which enables a pneumatic conveyor system to be operated, reliably and economically, from a single compressor.

Pneumatic conveyors, which are widely used to transport materials such as grain and powders, have hitherto always required a separate compressor for each line. This is due to the fact that if several lines are operated from one compressor, the air tends to take the path of least resistance, thus by-passing the more heavily loaded lines and eventually resulting in blockages.



Shadow photographs show how small surface imperfections can cause shock waves, top right, and how special treatment eliminates unnecessary pressure loss, lower right.



(Left) First use of sonic valves in bulk conveying equipment, installed recently at Liverpool.

The valve consists of a convergent-divergent nozzle made of aluminium and so proportioned that the air passing through it reaches the speed of sound. It is fitted with an adjustment by which the flow can be preset to any desired value, which is then held by the valve regardless of load changes.

The principle involved is well known: when the velocity of a gas through a constriction is equal to the velocity of sound, the mass-flow remains constant irrespective of downstream resistance. With a sonic valve interposed between a loaded line and the compressor, a pressure wave travelling toward the compressor as a result of a load change is halted at the valve throat, since the velocity of propagation is exactly equal to the opposing air velocity.

The introduction of a constriction to the system would be expected to produce a high pressure loss, and in fact this was the case at first. However, further research showed that by careful selection of the profile and special attention to the surface finish, it was possible to design a nozzle with negligible losses. This loss should be more than compensated by the gain in efficiency achieved by using compressors unsuitable for single blowing lines of the conventional type.

This type of system is inherently more stable and versatile than those in which each line is powered by its own compressor. In the latter system the air flow in the lines decreases with increased load, due to the compressor characteristics, whereas the air flow through the sonic valve remains constant.

In the first sonic conveyor system, which was recently installed at the bakery of William Crawford and Sons at Liverpool, all the blowing lines are powered from a central compressor installation and the whole plant can be controlled from a central room.

Compared with conventional systems, the sonic conveyor should give lower initial and running costs, and a greater flexibility in dealing with variations in conveying rates.

ISAAC NEWTON TELESCOPE

Parallax Work at the Cassegrain Focus

The Isaac Newton telescope, for which financial approval has been given to be built at the Royal Observatory at Herstmonceux Castle in Sussex, will be a parabolic reflector with an aperture of 98 in and a focal ratio of about 3 in. It will be designed to be used at the prime focus, Cassegrain focus and Coude focus. Special attempts will be made to design a Cassegrain combination for astrometry. The telescope tube will be held in an open fork with no North support. Nor will an attempt be made to house the observer, as is done in the 200 in and 120 in telescopes, at the prime focus inside the beam.

It is proposed to carry out a large programme of parallax work at the Cassegrain focus using the large aperture to observe much fainter stars than are accessible to the comparatively small reflectors now used on parallax work. Work of this kind was done on the Mount Wilson 100 in telescope which was not particularly designed for it, and it is thought that considerable improvements can be obtained by special design.

The spectroscopic programmes to be carried out will concentrate on the precise determination of radial velocity, especially in those cases where individual stellar velocities may be supposed to be important in connection with problems in stellar dynamics. In particular it is planned to provide a large grating spectrograph at the Coude focus with cameras of approximately 100 in, 60 in and 30 in focus. The prime focus will be available for the direct photography of stellar fields of interest in radio astronomy and will be equipped with a field correcting lens.

Book Reviews

ENCYCLOPAEDIA OF DRAUGHTSMANSHIP

Technical Drawing. By FREDERICK E. GIESECKE, ALVA MITCHELL and HENRY CECIL SPENCER. Fourth Edition. *MacMillan Company, 60 Fifth Avenue, New York 11, N Y, USA.* and *MacMillan Company, 10 South Audley Street, London, W1.* (52*s* 6*d*)

In a paper read a while ago to the Institution of Mechanical Engineers in London (30 November, 1956) Dr. Arms, the project manager of a large industrial combine, drew attention to the contrast in methods of training mechanical engineers in this country and in America. He said that, "The separation between technical and technological training is much sharper than it is in Britain." He found that a comparatively small number of American engineers undergo apprentice training, but frequently formal training, mainly in the form of classroom studies, is given after graduation from the university. A relatively small number are educated in technical colleges with standards comparable to the Higher National Certificate, which in this country can lead to professional status and corporate membership of an engineering institution. In common with various American books, this volume on technical drawing reflects this difference.

The book is a fourth edition, but previous editions are not well known in this country. It has been completely revised by H. C. Spencer, departmental director of the Illinois Institute of Technology, the only remaining member of the original group of three authors, assisted by several specialists in different aspects of drafting practice. It is a comprehensive work of 843 pages and is generally well written with very good illustrations. The range of material is extremely wide; in addition to ten chapters on general geometrical drawing and projection, three on pictorial projection and five on the production of working drawings, there are chapters on the specialised requirements for drawings on structural work, welding, piping and aeronautical work. There is also a chapter on patent procedure and patent drawings. The order of chapters could be improved to give a more logical sequence of progressive work.

The apparent objective is to produce a book to suit the high-school boy for his use throughout the four or five year course at the university, under the guidance of tutors. In view of this it is difficult to justify the meticulous amplification of detail in the presentation. Step by step descriptions are given of most minute operations such as the drawing of a line, or of the order in which lines should be drawn. In fact the detail is at times so meticulous that the reader becomes lost in the maze of instructions, It is somewhat surprising that with such punctilious attention to detail, certain discussions assume an understanding of principles which are not explained until subsequent chapters; for example, the use of orthographic views and reference to isometric views before a discussion of the principles of projection planes or of isometric projection. The elaboration of detail leads to repetition of precise instruction in several instances on certain matters, such as section lining. On the contrary, the chapter on intersections and developments is somewhat casual by comparison, and would be improved by greater detail and expansion.

There are excellent sets of exercises on sketching, correction of projected views, auxiliary projection, and on the production of working drawings of details and assemblies, but as would be expected, all the exercises and discussions of projection are related to the American third-angle projection. American standards (ASA) are quoted very freely in the text.

The desirability of expanding the book to embrace such a wide range is rather questionable. Considerable space (80 pages) is given to detailed discussion of various mathematical and statistical graphs, and of graphical applications including methods of differentiation and integration, and a further chapter is given on topographical map drawing. The section on shop processes is somewhat generalised, particularly in the description of machining methods, whilst the chapter on gearing is marred by the assumption that 14½° is still the standard pressure angle. There is a mere passing reference to stub teeth with 20° pressure angle. The 54 page appendix includes a very complete bibliography divided into subject matter sections and a large selection of American (ASA) standards. The bibliography does not mention any British book although in every important section comparable British books could be quoted.

With its complete use of third-angle projection and considerable quotation from ASA publications, the book is not directly useful to any group of British students, but lecturers in the subject would find considerable material for exercises in the large number of examples, and would profit by consideration of the detailed care in instruction.

C. J. ATKINS

COST OF A CALL

Telecommunications Economics. By T. J. MORGAN. *Macdonald and Company Limited, 16 Maddox Street, London, W1.* (50*s*)

The application of general economic principles to engineering studies is explained in this book and while it is addressed mainly to telecommunications engineers and the examples quoted are mainly of interest to them, the methods employed are equally applicable to those engaged in other forms of engineering where cost comparisons are required and where investigations into future operational expenditure are made. Various statistical approaches to forecasting from known data are discussed and are applied to the diverse problems encountered when designing telephone systems. Exchange buildings, exchange switching equipment, subscribers' line plant and cabling networks, trunk systems and multi-exchange areas are each given separate consideration in such a manner that no doubt is left in the mind of the reader as to which of several alternatives is the most economic method to apply.

The value of cost comparisons relies on the accuracy of the development forecasts on which they are based. The methods of compiling the forecasts described can be accepted as authoritative for countries whose economic conditions provide a relatively favourable background for the statistical methods of approach.

For telephone equipment, the normal planning period is 20 years. This is an interval of time which, under present conditions, provides wide scope for change, and therefore allows an equally great possibility of error in results of future operations calculated from known data.

Some variables can be reliably forecast and the methods applicable to a wide variety of problems met in engineering telephone systems are explained. But there are others which are unpredictable and the telecommunications engineer in public service administrations, when attempting to provide an efficient service for a very wide cross-section of the community is at the mercy of the instability of economic, political and social variations. Deficiencies and surpluses in supply, particularly the former, which have resulted from alterations in the demand pattern occurring too rapidly to be absorbed by forecasted trends are frequently met. Technical advances, especially in telecommunications, can also make a long-term statistical approach to a problem unrealistic.

Inflation is one important factor which does not receive mention. This is surprising because it is an influence that has been present to a greater or a lesser degree over a long period of history and cannot be ignored in calculating the 20 year cost forecasts advocated. The effect of inflation in this respect has been demonstrated by R. Krzychkowski in his paper on "Interest and Inflation in the Economic Planning of Telecommunications Systems" in the *A.T. & E. Journal* for October, 1957, and he shows that it is a very potent factor, not one to be neglected.

If the unpredictable causes subsequent errors of circuit provision in this country, it does so to a much greater degree in the overseas territories, to whose administrators the book is to a large degree addressed. There, long-range forecasting is hazardous to a high degree and to overcome some of the uncertainties of the future, it is necessary to introduce a maximum amount of flexibility into telephone development plans, particularly for subscribers' local distribution line schemes. It is possible that flexibility schemes may mean the installation of plant in the early stages of a development sequence which will be hard to justify when working from a pure statistical basis but this is one of the cases where experience and intimate local knowledge is a necessary background to supplement the mathematical approach advocated in the book.

The bibliography at the end of each chapter shows that many sources from United States and other foreign countries advanced in the field of telecommunications have been consulted. Here, Post Office methods tend to overshadow lines of approach other than their own and it is refreshing to know that the author has not submitted to domination from that source. He has, in addition included a considerable amount of original work.

The subject is still incomplete, however. Telecommunications has been defined as "any communication of information in verbal, written, coded or pictorial form by electrical means whether by wire or by radio" (*Chambers Technical Dictionary*). Verbal transmission by wire is the only form treated in detail in this work. Radio and other forms of telecommunication such as d.c. and tone telegraphy, telex and picture transmission, are only touched on briefly, or not at all. It is hoped that later editions of this work could include some notes on the economic approach to the provision of these subjects, particularly in relation to the international field where undersea cables are playing an increasingly important part as rivals to radio transmission.

W. J. S. RAE

DESCRIPTION BUT NO FUNDAMENTALS

Gas Turbines for Aircraft. By ARTHUR W. JUDGE. *Chapman and Hall Limited, 37 Essex Street, London, WC2.* (60*s*)

The object of this book, which is stated, in the preface, to be to " bridge the gap between the mostly descriptive and elementary type of text-book and the more academic kind " is a worthy one—there is a need for a compact source of information on the aircraft gas turbine, which is reasonably complete without going deeply into mathematics. There are many who would benefit from such a book—they have neither the time, the training nor the need to consider design methods, but want to know, in broad terms, why things are as they are, and what the background, limitations and future development possibilities are.

The gas turbine has, on the whole, been well served with literature of this kind, perhaps because its main development has been comparatively rapid (and spectacular in the aircraft field) and based on well understood principles which have been pursued logically.

This book, unfortunately, is not a very helpful contribution, though the table of contents looks very promising. The descriptive aspect certainly predominates and there are almost no mathematics or design data. A description of the history of the gas turbine is followed by discussions of its performance, as affected by various factors, and of different methods of improving it. Then there are chapters on the two main types of aircraft gas turbine and others dealing with particular components such as combustion, fuel, lubrication and starting systems. Finally after discussions of causes of failure, maintenance, silencing, materials and special types of engines there is a short chapter on thermodynamics.

The basic fault is revealed in the preface—the author is not sure of the fundamentals on which he builds the whole discussion. He omits altogether in his list of reasons why the gas turbine has been so widely adopted for aircraft propulsion, to mention the most important one of all—this, of course, is that the jet engine makes possible high speed flight because it can operate efficiently at aircraft Mach numbers which would cause the efficiency of a subsonic propeller to drop to an unacceptably low value. This same lack of fundamental understanding makes itself apparent from time to time throughout the book. For example, when heat exchangers are under discussion as one of the means of improving performance, the fact that the heat exchanger is thermodynamically, as well as practically, inappropriate to the jet engine is not mentioned at all, and the importance of pressure losses hardly referred to. So that readers might well wonder when the jet engine will be equipped with a heat exchanger and why isn't anyone doing anything about it?

The book is best where it keeps to descriptions, which together with the performance and other examples quoted, have been taken directly from the technical literature. However, the compilation has been very carelessly done—there is much repetition and many needless minor mistakes. For example on page 60 there are five incorrect equivalents given for fahrenheit and centigrade temperatures (which are used indiscriminately) and on page 287 it is stated that the development of the ASX engine (actually Armstrong Siddeley's own first gas turbine) was transferred from Metropolitan Vickers. There are too many of these to mention and although they are minor in themselves, their cumulative effect is sufficient to make the whole book suspect.

It is specially to be regretted that a largely descriptive book of this kind should contain so many errors, many of which are difficult for anyone coming fresh to the subject to discern. It is unfortunate that the author has strayed into a field where he is not familiar with either the basic philosophy or the everyday practice and has thereby produced a book which is far from worthy of the achievements of the British aircraft gas turbine industry.

J. HODGE

The Reviewers

Mr. C. J. Atkins, A.M.I.Mech.E., A.M.I.Prod.E., A.M.B.I.M., is senior lecturer in the mechanical engineering department of Croydon Technical College, and co-author of *Practical Engineering Drawing*.

Mr. W. J. S. Rae, A.M.I.E.E., is engineer in charge of development and operation of overseas telephone systems in the engineer-in-chief's department, Cable and Wireless Limited. Before 1952, he was a member of the engineering department at Ericsson Telephones Limited.

Mr. J. Hodge, M.A., A.M.I.Mech.E., A.F.R.Ae.S., M.A.S.M.E., has recently joined Holman Brothers Limited as chief engineer. He was formerly chief engineer of Power Jets (Research and Development) Limited.

NEW BOOKS

Corrosion of Metals by Vapours from Organic Materials. By VERA E. RANCE and H. G. COLE. Published for the *Admiralty and Ministry of Supply Inter-Service Metallurgical Research Council* by *Her Majesty's Stationery Office, York House, Kingsway, London, WC2.* (2*s*)

The Polishing of Roadstone in Relation to the Resistance to Skidding of Bituminous Road Surfacings. By D. J. MACLEAN and F. A. SHERGOLD. Road Research Technical Paper No. 43. Published for the *Road Research Laboratory, Department of Scientific and Industrial Research* by *Her Majesty's Stationery Office, York House, Kingsway, London, WC2.* (3*s*)

Graded Examples in Mathematics for National Certificate Students with Hints and Solutions. By E. G. SHALDERS. Books One, Two and Three. *Blackie and Son Limited, 17 Stanhope Street, Glasgow, C4.* (5*s each*)

In each of these booklets the author has aimed to present the syllabus in such a way that (*a*) sufficient mathematics is taught in time to be used by the student in the engineering subjects, (*b*) each topic is dealt with twice, thus tending to keep up a form of continuous revision, and (*c*) a student absent for a week can regain lost ground.

Workshop Arithmetic. By HENRY A. DARLING. *Blackie and Son Limited, 17 Stanhope Street, C4.* (6*s*)

This course of exercises provides a groundwork for the examinations of the City and Guilds Institute and of the National Certificate. It aims to show how the rules of arithmetic may be applied to the solution of the elementary problems which trade students meet in the course of their work.

The British Railway Locomotive 1803-1853. Compiled by G. F. WESTCOTT. Published for *The Science Museum* by *Her Majesty's Stationery Office, York House, Kingsway, London, WC2.* (3*s* 6*d*)

A brief historical review of the technical development of the locomotive introduces this delightful collection of annotated reproductions of drawings and engravings of historic British locomotives.

On the Shelf

By Frank H. Smith

In the *BSI News* for February there is a paragraph advertising the attempt (under the auspices of the Ford Foundation) to compile an international directory of graphical signs and symbols used in trade and industry, the arts and other spheres. Anybody with ideas on this point should get in touch with Mrs. Marie Neurath of the Isotype Institute Limited, 68 Oxford Street, London, W1.

Harrap (182 High Holborn, WC1) are publishers who specialise in dictionaries and their January leaflet announces two new ones. A Portuguese-English Dictionary is said to be the first to appear since 1887 (and do not jump down my throat—there have been English-Portuguese versions) and a pre-war favourite " Der grosse Duden Bildwörterbuch " reappears in the list. The latter is a pictorial dictionary of school library calibre.

A note comes from the Engineering Societies Library (29 West 39th Street, New York 18) of their latest bibliography. It is No. 13, is on Shell Molding (sic) and has 200 annotated references from 1952 to 1958. $2.

Those Americans are mucking about with their journal titles again. The hitherto *Jet Propulsion* published by the American Rocket Society, is now *ARS Journal*, which strikes me as a step in the right direction. In explaining the reasons for the change in an editorial the Editor points out that the ARS membership has risen from 1,200 in 1951 (with three sections) to 12,000 at the time of writing (with 42 sections). And boy, is that growth! What is more, they are growing at the rate of 50 per cent per annum.

Applied Mechanics Reviews is catching the habit of change but in their case they have made it on the classification of their topics. (Topic is the word they use and it makes a nice change from " subject "). They now use five very general headings, 50 more specific headings and over 500 detailed headings.

The Institute of the Aeronautical Sciences has got its teeth well into this business of change. They're changing everything. First they change the title of both of their journals so that that magic American word " space " could be incorporated and now the preprints that they have been putting out for years are to be called Reports. To English librarians " preprints " always was a bit confusing because the pre referred to before the meeting and not to before proper printing. In 99 cases out of a hundred they never saw any other form. The reports will break new ground in that the serial number will be preceded by the year of publication, e.g., 59/4.

" The United States National Museum 1958 Annual Report " is a cheerful record of renovation and rebuilding. Looking under " Science and Technology " one finds the accent on biology with an illustration of a sheer impossibility—a transparent woman. It is a model of course, for nobody has seen or ever will see through a woman. Items of engineering interest such as Borden vacuum pans, Olds gasoline engine, the Howard tower clock and so on have been renovated during the year but the things that interest me are the Indian exhibits with feathered headdresses, the Winchester belonging to Chief Sitting Bull and other similar relics that bring the old TV to life. Cor mate!

Henry Wiggin and Company (Wiggin Street, Birmingham 16) are apparently going in for the referee business. Their latest publication (free) is entitled " Wiggin Nickel Alloys v. Fluorine and Fluorine Compounds." My money is on Wiggin and their alloys.

Rolls-Royce have (and it may not be generally known) a Railway Traction Department which issues *Newsletters*. The first (July, 1958) was on Torque Converters and the second (December) on a complete propulsion equipment.

MEETINGS AND PAPERS

Association of Supervising Electrical Engineers
WOLVERHAMPTON
"Light Sources, with Particular Reference to Electro-Luminescence," by G. V. McNeill. Chamber of Commerce, District Bank Chambers, Lichfield Street, Wolverhampton. Wed., 18 Mar., 7.45 p.m.

British Computer Society
LONDON
"An Approach to Learning and Teaching Machines," by C. E. G. Bailey. Northampton College of Advanced Technology, St. John Street, EC1. Wed., 18 Mar., 6.15 p.m.*

British Institution of Radio Engineers
LONDON
"Instrumentation in Field Physiology," by Dr. H. Wolff. Medical Electronics Group. London School of Hygiene and Tropical Medicine, Keppel Street, WC1. Thurs., 19 Mar., 6.30 p.m.*
EDINBURGH
"Application of Magnetic Amplifiers to Electrical Switching," by J. A. Purdie. Scottish Section. Department of Natural Philosophy, The University, Drummond Street, Edinburgh. Fri., 20 Mar., 7 p.m.

Chemical Engineering Group
NOTTINGHAM
"Extraction of Thorium," by W. D. Jamrack, R. A. Wells and Dr. J. H. Buddery. Technical College, Burton Street, Nottingham. Thurs., 19 Mar., 7.30 p.m.

Chemical Society
NEWCASTLE UPON TYNE
"Polyethers," by Professor G. Gee. Newcastle upon Tyne Branch. Chemistry Department, King's College, Newcastle upon Tyne. Wed., 18 Mar., 6.30 p.m.
SHEFFIELD
"Colour," by Dr. E. Averton. Sheffield Branch. City Memorial Hall, Sheffield. Fri., 20 Mar., 7.30 p.m.

Combustion Engineering Association
BIRMINGHAM
"Use of Small Coals for Steam Raising," by E. Otty. Midland Region. Chamber of Commerce, New Street, Birmingham. Wed., 18 Mar., 10 a.m.

Diesel Engineers and Users Association
LONDON
"Development of the Vee-type Engine," by G. Hopwood. Institute of Marine Engineers, 76 Mark Lane, EC3. Thurs., 19 Mar., 2.30 p.m.

Engineers' Guild
CARDIFF
Luncheon Meeting. South Wales and Monmouthshire Branch. Old Arcade Inn, Church Street, Cardiff. Fri., 20 Mar., 12.45 p.m.

Illuminating Engineering Society
BRISTOL
"Airport Lighting," by J. G. Holmes. Bath and Bristol Centre. Showrooms of Gardiner, Sons & Co., Ltd., Broad Plain, Bristol. Mon., 16 Mar., 7 p.m.
COVENTRY
"Architecture of Light," by Rolf Helburg. Birmingham Centre. St. Mary's Hall, Coventry. Fri., 20 Mar., 6 p.m.

Institute of Marine Engineers
LONDON
Annual General Meeting. "A Review of National Certificate Schemes," by C. H. Taylor-Cook. Education Group. Tues., 17 Mar., 5.30 p.m.*
"Gas Turbines," by Commander A. A. C. Gentry, R.N. Lloyd's Register Lecture for Students. Thurs., 19 Mar., 5.30 p.m.*
"Petroleum Refining," by E. H. Wild. Woolwich Polytechnic, SE18. Tues., 17 Mar., 7 p.m.
LEEDS
"Oil-Operated Gears for Ship Propulsion," by I. Wans. Kingston-upon-Hull and East Midlands Section. Great Northern Hotel, Leeds. Thurs., 19 Mar., 7.30 p.m.

Institute of Metals
SWANSEA
Annual General Meeting. "Review of Current Research Work in the Metallurgy Department, University College, Swansea," by Professor H. O'Neill. South Wales Local Section. University College, Singleton Park, Swansea. Tues., 17 Mar., 6.30 p.m.*

Institution of Chemical Engineers
LONDON
Spring Meeting. "Methods of Improving Heat Transfer from Condensing Steam and Their Application to Condensers and Evaporators," by D. C. P. Birt and others; "Investigation of Air-Flow in a Spray Drier by Tracer and Model Techniques," by G. Place and others; "Entrainment in Evaporators," by F. H. Garner and others; "Purification of Hydrogen for Distillation: Part II," by W. H. Denton and others; and "Entrainment in Turbulent Fluid Jets," by M. B. Donald and H. Singer. Church House, Westminster, SW1. Tues., 17 Mar., 9.30 a.m.

Institution of Civil Engineers
LONDON
James Forrest Lecture: "Roads and Road Usage—The Application of Science," by Dr. W. H. Glanville. Tues., 17 Mar., 5.30 p.m.*

Institution of Electrical Engineers
LONDON
"Electrical Uses of Atomic Spin," by G. Phillips. Measurement and Control Section. Tues., 17 Mar., 5.30 p.m.*
"New Amplifying Techniques," by C. W. Oatley. Radio and Telecommunication Section. Wed., 18 Mar., 5.30 p.m.*
"Something for Nothing? Heat Pump Achievements," by G. O. McLean. London Graduate and Student Section. Mon., 16 Mar., 6.30 p.m.*
BATH
"Electrification of the Atomic Energy Authority's Industrial Group Factories," by J. W. Binns and W. J. Outram. Western Centre. Bath Technical College, Bath. Tues., 17 Mar., 6 p.m.*
LEEDS
Faraday Lecture on "Automation," by Dr. H. A. Thomas. North Midland Centre. Town Hall, Leeds. Mon., 16 Mar., 7 p.m.
NEWCASTLE UPON TYNE
Faraday Lecture on "Automation," by Dr. H. A. Thomas. North Eastern Centre. City Hall, Newcastle upon Tyne. Thurs., 19 Mar., 7 p.m.

Institution of Engineering Inspection
MANCHESTER
"Surface Finish," by R. C. Spragg. North Western Branch. Engineers' Club, Albert Square, Manchester. Thurs., 19 Mar., 7.30 p.m.

Institution of Engineers-in-Charge
LONDON
"Power Factor Correction," by G. E. Bishop. Caxton Hall, off Victoria Street, SW1. Wed., 18 Mar., 6.30 p.m.*

Institution of Engineers and Shipbuilders in Scotland
GLASGOW
"A Review of Current Ship Hydrodynamics Research," by Dr. F. H. Todd. Tues., 17 Mar., 6.30 p.m.*

Institution of Heating and Ventilating Engineers
LEEDS
Annual Meeting and Discussion on "Steam Cars." Powolnys Restaurant, Leeds. Wed., 18 Mar., 7.30 p.m.

Institution of Locomotive Engineers
LONDON
Annual General Meeting. "The Electro-Gyro Locomotive," by T. E. Green and J. K. Gessler. Institution of Mechanical Engineers, 1 Birdcage Walk, SW1. Wed., 18 Mar., 5.30 p.m.*

Institution of Mechanical Engineers with Institution of Civil Engineers and Institution of Electrical Engineers
LONDON
Graham Clark Lecture: "Engineering in an Expanding Economy," by Professor Sir Arnold Plant. Joint Meeting. Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, SW1. Fri., 20 Mar., 6 p.m.*

Institution of Mechanical Engineers
LONDON
James Clayton Lecture: "The Creation of a Country's Automobile Industry: The Engineer's Viewpoint," by Wifredo P. Ricart. Automobile Division. Tues., 17 Mar., 6 p.m.*
BIRMINGHAM
"Materials in Service of Mechanical Engineers," by R. G. Brown. Midland Branch. James Watt Memorial Institute, Great Charles Street, Birmingham. Thurs., 19 Mar., 6 p.m.
MANCHESTER
"Special Design and Construction Features of the Bradwell Nuclear Power Station," by G. R. Inglis. North Western Branch. Engineers' Club, Albert Square, Manchester. Thurs., 19 Mar., 6.45 p.m.
YORK
"Jodrell Bank Radio Telescope," by H. C. Husband. Royal Station Hotel, York. Thurs., 19 Mar., 7.30 p.m.

Institution of Mining and Metallurgy
LONDON
"Recovery of Semi-Heavy Minerals in Jigs," by F. A. Williams; and "Santa Barbara Mill, Chihuahua, Mexico," by D. C. Shelton. Geological Society, Burlington House, Piccadilly, W1. Thurs., 19 Mar., 5 p.m.*

Institution of Plant Engineers
ROCHESTER
"Some Applications of Plastics in Industry," by Dr. C. L. Child. Kent Branch. King's Head Hotel, High Street, Rochester. Wed., 18 Mar., 7 p.m.

Institution of Production Engineers
LONDON
Annual General Meeting. "The Diploma of Technology and the Place of Human Studies in Its Syllabus," by A. C. Leyton. Royal Empire Society, Northumberland Avenue, WC2. Thurs., 19 Mar., 7 p.m.
SHEFFIELD
"Ergonomics in Industry," by K. F. H. Murrell. East and West Ridings Region. Grand Hotel, Sheffield. Tues., 17 Mar., 6.30 p.m.

Institution of Structural Engineers
LEEDS
"Prestressed and Reinforced-Concrete Construction in the USSR," by Professor V. V. Mikhailov. Yorkshire Branch. The University, Leeds. Wed., 18 Mar., 6.30 p.m.

Liverpool Engineering Society
LIVERPOOL
"Bailey Bridges and Pontoon Bridges," by H. Elliott. Wed., 18 Mar., 6 p.m.

Manchester Association of Engineers
MANCHESTER
Annual General Meeting. "Production Investigations Applied in Practice," by Dr. N. Dudley and Dr. F. Koenigsberger. Engineers' Club, Manchester. Fri., 20 May, 6.45 p.m.

Manchester Metallurgical Society
MANCHESTER
"Metallurgical Background of Casting Production," by A. Cibula. Central Library, Manchester. Wed., 18 Mar., 6.30 p.m.

Modular Society
LONDON
Open Discussion Meeting. Building Centre, Store Street, WC1. Wed., 18 Mar., 6 p.m.

Reinforced Concrete Association
LONDON
"Use of Lightweight Concrete for Reinforced-Concrete Structures," by A. Short. 11 Upper Belgrave Street, SW1. Wed., 18 Mar., 6 p.m.*

Royal Aeronautical Society
LONDON
"Long-Range Missiles," by E. C. Cornford. Institution of Civil Engineers, SW1. Thurs., 19 Mar., 6 p.m.*

Royal Institution
LONDON
"Man as a Controller of Flight Vehicles," by Air Commodore W. K. Stewart. Fri., 20 Mar., 9 p.m.

Royal Meteorological Society
LONDON
Various short papers. Wed., 18 Mar., 5 p.m.*

Royal Society
LONDON
"Atomisation of Hydrogen on Tungsten," by D. Brennan and P. C. Fletcher. Thurs., 19 Mar., 4.30 p.m.*

Royal Society of Arts
LONDON
"River Pollution: An Experiment in the Thames Estuary," by Dr. B. A. Southgate. Wed., 18 Mar., 2.30 p.m.

Royal Statistical Society
LONDON
"ERNIE: A Mathematical and Statistical Analysis," by W. E. Thomson. London School of Hygiene and Tropical Medicine, Keppel Street, WC1. Wed., 18 Mar., 5.15 p.m.*

Scientific Film Association
LONDON
A Symposium on "Recent Developments in Research Films." Mezzanine Cinema, Shell-Mex House, Strand, WC2. Wed., 18 Mar., 6.30 p.m.

Sheffield Metallurgical Association and Sheffield Society of Engineers and Metallurgists
SHEFFIELD
"Conversion of a High-Lift Blooming Mill to a Universal Slabbing Mill," by C. E. H. Morris and R. N. Dale. The University, St. George's Square, Sheffield. Mon., 16 Mar., 7 p.m.

Society of Chemical Industry
LONDON
"Economic Aspects of Corrosion," by A. Keynes. Corrosion Group. Wed., 18 Mar., 6.30 p.m.*

Society of Instrument Technology
NEWCASTLE UPON TYNE
"Operating Experiences on Automatic Control of Large Steam Generators," by J. S. Holt. Newcastle Section. King's College, Stephenson Buildings, Newcastle upon Tyne. Wed., 18 Mar., 7 p.m.

South Wales Institute of Engineers
CARDIFF
"Electrical Aspects of the Continuous Miner at Trelewis Drift Mine," by H. Pritchard. Thurs., 19 Mar., 6 p.m.

Women's Engineering Society
LONDON
"Design and Use of Textile Finishing Machinery," by H. Ellis and J. H. Hilton. London Branch. Hope House, 45 Great Peter Street, SW1. Thurs., 19 Mar., 7 p.m.*

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this feature should reach the Editor not later than three weeks before the date of the meeting.

* An asterisk is placed where it is understood that refreshments are available prior to the time stated.

Association of Supervising Electrical Engineers, 23 Bloomsbury Square, London, WC1. (LANgham 5927.)
British Computer Society, Finsbury Court, Finsbury Pavement, London, EC2. (MONarch 6252.)
British Institution of Radio Engineers, 9 Bedford Square, London, WC1. (MUSeum 1901.)
Chemical Engineering Group, 14 Belgrave Square, London, SW1. (BELgravia 3647.)
Chemical Society, Burlington House, Piccadilly, London, W1. (REGent 0675.)
Combustion Engineering Association, 6 Duke Street, St. James's, London, SW1. (WHItehall 5536.)
Diesel Engineers and Users Association, 18 London Street, London, EC3. (ROYal 2393.)
Engineers' Guild, 78 Buckingham Gate, London, SW1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria Street, London, SW1. (ABBey 5215.)
Institute of Marine Engineers, Memorial Building, 76 Mark Lane, London, EC3. (ROYal 8493.)
Institute of Metals, 17 Belgrave Square, London, SW1. (BELgravia 3291.)
Institution of Chemical Engineers, 16 Belgrave Square, London, SW1. (BELgravia 3647.)
Institution of Civil Engineers, Great George Street, London, SW1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, WC2. (TEMple Bar 7676.)
Institution of Engineering Inspection, 28 Victoria Street, London, SW1. (ABBey 3794.)
Institution of Engineers-in-Charge, 13 Grange Close, Edgware, Middlesex. (MILl Hill 3543.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C2. (Central 5181.)
Institution of Heating and Ventilating Engineers, 49 Cadogan Square, London, SW1. (SLOane 3158.)
Institution of Locomotive Engineers, 28 Victoria Street, London, SW1. (ABBey 6672.)
Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, London, SW1. (WHItehall 7476.)
Institution of Mining and Metallurgy, 44 Portland Place, London, W1. (LANgham 3802.)
Institution of Plant Engineers, 2 Grosvenor Gardens, London, SW1. (SLOane 0469.)
Institution of Production Engineers, 10 Chesterfield Street, London, W1. (GROsvenor 5254.)
Institution of Structural Engineers, 11 Upper Belgrave Street, London, SW1. (SLOane 7128.)
Liverpool Engineering Society, 9 The Temple, 24 Dale Street, Liverpool 2. (Central 3717.)
Manchester Association of Engineers, 18 Booth Street, Manchester 2. (Central 1717.)
Manchester Metallurgical Society, The Kennedy Press, Ltd., 31 King Street West, Manchester 3.
Modular Society, 22 Buckingham Street, London, WC2. (TRAfalgar 4567.)
Reinforced Concrete Association, 94-98 Petty France, London, SW1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton Place, London, W1. (GROsvenor 3515.)
Royal Institution, 21 Albemarle Street, London, W1. (HYDe Park 0669.)
Royal Meteorological Society, 49 Cromwell Road, South Kensington, London, SW7. (KENsington 0730.)
Royal Society, Burlington House, Piccadilly, London, W1. (REGent 3335.)
Royal Society of Arts, John Adam Street, Adelphi, London, WC2. (TRAfalgar 2366.)
Scientific Film Association, 3 Belgrave Square, London, SW1. (BELgravia 6188.)
Sheffield Metallurgical Association, 64 Crescent Road, Sheffield 7. (Sheffield 52865.)
Sheffield Society of Engineers and Metallurgists, University of Sheffield, St. George's Square, Sheffield 1. (Sheffield 24071.)
Society of Chemical Industry, 14 Belgrave Square, London, SW1. (BELgravia 3681.)
Society of Instrument Technology, 20 Queen Anne Street, London, W1. (LANgham 4251.)
South Wales Institute of Engineers, Park Place, Cardiff. (Cardiff 23296.)
Women's Engineering Society, 25 Foubert's Place, London, W1. (GERrard 5212.)

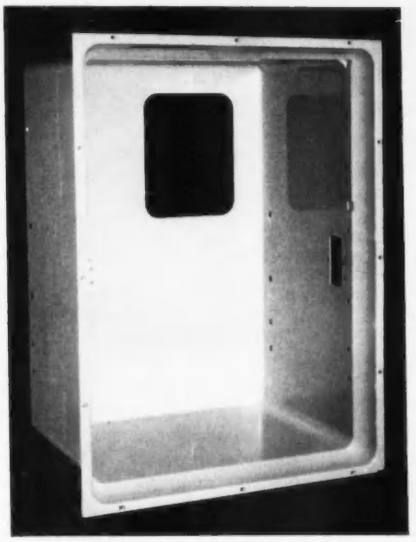
Metals and Materials

LARGE INJECTION MOULDINGS IN POLYSTYRENE

A Windsor AP335 injection moulding machine installed at Ekco Plastics' works at Southend-on-Sea is being used to make complete refrigerator liners from a 104 oz shot of BX high impact polystyrene. The moulding has dimensions of 26½ in by 19⅜ in by 14 in and is formed in one single action complete with holes, the injection stroke taking 3¼ seconds, and being repeated in this set-up every 70 seconds.

The moulding machine is fitted with the Autoplas pre-plasticising unit with a capacity of 420 lb of polystyrene per hour. The swept volume of the injection stroke is 335 cu. in or approximately 210 oz of this plastic. Although this is the first machine of such large capacity to be put into commission in Great Britain, similar Windsor machines have been in continuous use on the Continent for some time. The information thus accumulated has contributed to the smooth working of this machine in yielding sound, stress-free mouldings. The dies for this moulding weigh 7¾ tons and are made in Ni-Cr steel, the outside surface of the male die being hand polished.

The liner is incorporated in a new refrigerator made by Frigidaire.



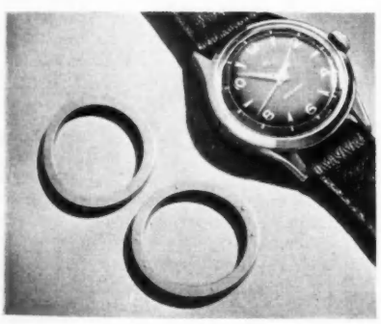
Single shot polystyrene moulding for refrigerator.

PRINTING AND DRAWING PAPER

A new formula for the coating of Ammonax blue-line ammonia-developed printing papers, which combine a high printing speed with density of line, has been developed by Hall Harding. As the new coating will also produce legible copies from materials previously considered unsatisfactory for photocopying, a wider choice of drawing media is available to the drawing office, particularly where the draughtsman does not need to trace. A good quality rag detail paper with all its attendant advantages (toughness, easy erasure, suitability for microfilming) can be employed without any reduction of either quality or quantity in the output from the print room. It is claimed that not only can printing speeds be increased up to three times with low-intensity light sources without loss of density, but that reproductions from old, worn drawings can be improved, and at much higher speeds, and that this paper is suitable for copying many single-sided documents and opaque originals from which satisfactory copies have not previously been obtainable. Superspeed materials are available in rolls 30 in and 40 in wide, 10, 20 or 50 yards long, and in cut sheets.

Duralax translucent drawing papers, also made by Hall Harding, are now being made in two weights, with either a smooth or a matt surface. Advantages claimed for Duralax include its storage properties—drawings made on it will keep for years without any sign of discoloration or brittleness. No edge binding is necessary. It can be guaranteed to maintain dimensional stability to a very high degree; and the synthetic resins used in the transparentising process are moisture repellent.

Samples of Ammonax and Duralax materials will be sent on request to the makers at Stourton House, Dacre Street, London, SW1. Ready supplies of the Duralax papers are available from any one of the 23 Hall Harding branches in the United Kingdom.



The counterweight in this self-winding watch is cut from Mallory 1000.

SINTERED HIGH DENSITY METAL

Johnson Matthey announce that they are now producing and marketing Mallory 1000, a machineable high density material composed of tungsten, nickel and copper and made by a powder metallurgy technique. Mallory 1000 has a uniform structure, a proof strength of 11 tons per sq. in and the high density of about 16·9. As the material may be subjected to all normal machining and grinding processes, it is suitable for the manufacture of components where high mass coupled with high strength and small volume are important considerations. Components fabricated from Mallory 1000 are finding increased application as counterbalances for aircraft control surfaces, balances for flywheels, inertia members in such instruments as accelerometers, and as rotating inertia members, where strong precision-machined rotors are required in a limited space. A self-winding watch by Timex incorporates a counterweight cut from a Mallory 1000 ring of the type illustrated.

A further application of the metal is in radiation shielding. It effectively absorbs gamma rays and can also be used for the shielding of neutron-emitting fission by-products, provided that the intensity of bombardment is relatively low. Such low intensity neutron bombardment causes only moderate activity in the metal.

Mallory 1000 is supplied in special pressed shapes as well as in the form of round and rectangular bars. Further information is available from the company's head office at 73-83 Hatton Garden, London, EC1.

PTFE INSULATED INSTRUMENT WIRE

Instrument wire insulated with ptfe for use in electrical instruments and equipment is now available from Siemens Edison Swan Limited, 155 Charing Cross Road, London, WC2. There are currently two types in production, for use at voltages up to 500 volts r.m.s. and 1,000 volts r.m.s. They are to Ministry of Supply (Air) Specification EL1930, types B and C. Applications are expected to be wide, notably in the aircraft, electronic and chemical industries. The insulation is made in 11 colours. The wire, for use where conductor temperatures of between minus 75° C and 250° C are experienced, has either single or stranded copper wires each silver plated to a radial thickness of not less than 0·00003 in. The ptfe is extruded, which permits a high degree of concentricity to be obtained. While the insulation is not loose, it can be cleanly stripped for connections. Electrically, ptfe has high dielectric strength and low power factor. It offers complete chemical resistance to all known solvents except molten sodium and fluorine gas. Ptfe instrument wire is non-chafing owing to low coefficient of friction, is highly flexible, and will not harden or perish.

PIEZOELECTRICS

Bush Crystal Company Limited, of Shore Road, Hythe, Southampton, announce that commercial production of new piezoelectric materials has now started. These are polycrystalline ceramics based on a lead zirconate-titanate solid solution; they possess a very high conversion efficiency and are useable up to 250° C.

Applications for the range of piezoelectric ceramics include pick-up elements, accelerometer and pressure cartridges, flaw detection probes and high power ultrasonic transducers. The temperature characteristics of one type are said to make ceramic filter elements a possibility.

Construction

STRUCTURES TO WITHSTAND EARTHQUAKES

The drafting of building regulations in earthquake areas for the structural designer are discussed. From a study of the response of simple single mass oscillators to the accelerographs recorded in recent strong earthquakes in the western United States an idealisation of earthquake motion as a random series of impulses is developed. Theoretical consideration of the response which may be expected to random impulses gives a principle of value in designing against future earthquakes. The use of computers to enable the response of more complex idealised structures is also examined.

By D. A. Howells
M.A., A.M.I.C.E.

THE recent rapid developments in the understanding of the effects of earthquakes on structures has two causes. In the first place, it is the fruit of the United States Coast and Geodetic Survey's Strong Motion Programme which began in the early 1930's. In the second place, the increasing use of analogue and digital computers has made possible the solution of problems of dynamic loading of structures which, a few years ago, were considered impossibly laborious. This article, therefore, falls into three parts. The first deals with those characteristics of earthquakes which have significant effects on structures and may be generalised and projected into the future; the second with the response of more complex structures to dynamic loads; and the third part reviews the implications for the drafting of Codes of Practice, and for the structural engineer.

It is necessary to idealise any problem and consider a model subjected to a drastically reduced number of variables to bring the problem within the scope of analysis at all; the choice of a simple model which none-the-less corresponds closely to reality is basic to the approach. When, as in the case of the study of earthquakes, the number of variables remains large and the problem still remains very complex, it is necessary to make further assumptions and limit the generality in order to deal with a particular aspect of the problem. Any discussion of the conclusions must always be made within the limits set by these assumptions, but a designer must bear in mind the other aspects which will affect a real structure.

EARTHQUAKE CHARACTERISTICS

Most earthquakes, including the most widespread and disastrous ones, are caused by the rupture of the earth's crust below the surface in shear along planes of weakness (faults) where such movements have occurred in the past and by the consequent release of deformation strain energy. The region of origin of the shock (the focus) is usually less than five miles below the epicentre at the surface. In very intense earthquakes, the fault may rarely become visible as a rupture of the surface.

Any combination of inertia and elasticity will be set in wave motion by such a shock and waves will travel outward through an elastic medium. The earth's crust is far from elastic, but the waves which travel through it can be identified with those postulated by the theory of elasticity. An impulse originating at a point in a homogeneous infinite elastic solid will produce two types of waves, compression waves known to seismologists as P waves, and transverse waves known as S waves. The velocity of propagation of S waves is always less than that of P waves, the relation between them depending on Poisson's ratio. In a semi-infinite or stratified solid, several other types of waves may be produced. These waves, called surface waves, travel along and parallel to the surfaces involved. The arrival of P, S and surface waves in succession at a seismograph in the vicinity of the epicentre of an earthquake can usually be identified, but the records are very complex, largely because of reflection and refraction at the irregular surface and strata boundaries. It is the irregular motion corresponding to surface waves in the simplified model which is the main cause of damage to buildings.

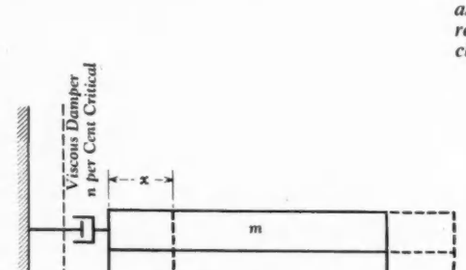
The classical seismograph behaves very much as a displacement meter and is a delicate instrument unsuited to the recording of ground motions sufficiently strong to damage buildings. The United States Coast and Geodetic Survey's Strong Motion Programme has involved the design of seismographs suitable for recording damaging ground motions and the installation of a number of these in basements and at other points in buildings at various places in the earthquake region of the western United States. These instruments are primarily acceleration meters. A number of fairly damaging earthquakes have occurred in the region and records of the accelerations of basements of buildings, treated as records of the ground motion, are now available for study.

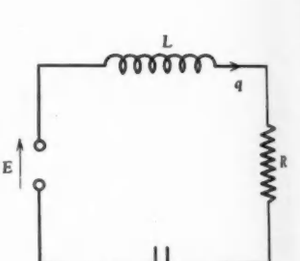
RESPONSE SPECTRUM

In considering the relationship between an earthquake and a building from the point of view of the characteristics of the earthquake, a very simplified model is taken for the building. This is treated as an elastic single degree of freedom system, subject to viscous damping. For the present, the earthquake is treated as one dimensional, only one component of the recorded motion of a point on the ground being considered at a time.

Let us consider a system of a single mass m, a linear spring of spring constant k and a viscous damper with a constant of proportionality a between the damping force and the relative velocity, as shown in Fig. 1; this illustration also shows the electrical analogue of a mechanical single-mass system. The absolute horizontal displacement of the mass will be denoted by x and that of the ground by x_g. The extension of the spring is $x - x_g$: the velocity of mass relative to the ground is $\dot{x} - \dot{x}_g$, while the absolute acceleration of the ground is $\ddot{x}_g$ and that of the mass is $\ddot{x}$. For critical damping $a_{cr} = 2\sqrt{m\,k}$ and it is convenient to denote the damping by n, the fraction of critical camping,

Fig. 1 Simple model representing an earthquake as a one-dimensional phenomenon, with only one recorded direction of motion. On the right is the circuit for an electrical analogue of such a model.





so that $n = \dfrac{a}{2\sqrt{m\,k}}$. The natural free period of the undamped system, $T = 2\pi\sqrt{\dfrac{m}{k}}$, is a convenient variable combining the characteristics of the spring and the mass. The equation of motion is

$$m\ddot{x} + a(\dot{x} - \dot{x}_g) + k(x - x_g) = m\ddot{x}_g(t) \quad . \quad . \quad . \quad (1)$$

The solution of this is

$$x - x_g = -\frac{T}{2\pi\sqrt{1-n^2}} \int_o^t \ddot{x}_g(\tau)\, e^{-\frac{2\pi n}{T}(t-\tau)} \times \sin\frac{2\pi}{T}\sqrt{1-n^2}\,(t-\tau)\,d\tau \quad . \quad . \quad . \quad . \quad (2)$$

When n is less than about 0·2, as is the case for

nearly all structures, $\sqrt{1-n^2}$ is approximately equal to unity and the expression may be simplified to

$$x - x_g = -\frac{T}{2\pi}\int_o^t \ddot{x}_g(\tau)\, e^{-\frac{2\pi n}{T}(t-\tau)} \times \sin\frac{2\pi}{T}(t-\tau)\,d\tau \quad . \quad (3)$$

The velocity and acceleration of the mass may be obtained by differentiating and the results may be expressed in the form

$$\dot{x} - \dot{x}_g = -\int_o^t \ddot{x}_g(\tau)\, e^{-\frac{2\pi n}{T}(t-\tau)} \times \sin\frac{2\pi}{T}(t-\tau-\alpha)\,d\tau \quad . \quad . \quad (4)$$

$$\ddot{x} = +\frac{2\pi}{T}\int_o^t \ddot{x}_g\, x(\tau)\, e^{-\frac{2\pi n}{T}(t-\tau)} \times \sin\frac{2\pi}{T}(t-\tau+\beta)\,d\tau \quad . \quad . \quad (5)$$

where $\frac{2\pi}{T}\alpha = \tan^{-1}\left(\frac{1}{n}\right)$

and $\frac{2\pi}{T}\beta = \tan^{-1}(2n)$

In the derivations n^2 has again been treated as negligible in relation to unity.

By supplying the function $\ddot{x}_g(t)$ as the input to an electrical analogue of the vibrating system the integrals may be evaluated and the response R of the system is obtained. This, which may be displacement velocity or acceleration, takes the form of an oscillation on which is superimposed a varying amplitude. To determine the greatest stresses to which a structure is subjected the maximum value of the amplitude is required. For a given record of ground acceleration, the value of R_{max} depends on two variables, T and n, and a set of curves of R_{max} plotted against T for various values of n is referred to as the response spectrum of the ground motion. It has become customary for investigators to determine the maximum value of the integral

$$S_v = \left[\int_o^t \ddot{x}_g(\tau)\, e^{-\frac{2\pi n}{T}(t-\tau)} \times \sin\frac{2\pi}{T}(t-\tau)\,d\tau\right]_{max} \quad (6)$$

which occurs in the expression for displacement, equation 3. This integral has the dimensions of a velocity and its graph is referred to as the velocity response spectrum. Fig. 2 shows a typical velocity response spectrum. The concept of a response spectrum was introduced by Biot and described in his classical paper, "Analytical and Experimental Methods in Engineering Seismology."[1]

The structure oscillates with a period approximating to its natural period and if this natural period is short in comparison with the duration of the earthquake, as is the usual case, then if the earthquake impulses occurring during a time T/2 are neglected, the maximum velocity will occur within the same half-wave as the maximum displacement and acceleration, so that the following approximate relations hold:—

$$(x - x_g)_{max} = \frac{T}{2\pi}S_v \quad . \quad . \quad (7)$$

$$(\dot{x} - \dot{x}_g)_{max} = S_v \quad . \quad . \quad . \quad (8)$$

$$\ddot{x}_{max} = \frac{2\pi}{T}S_v \quad . \quad . \quad (9)$$

Within the limits of this approximation, it is seen that S_v represents the actual maximum velocity reached by the structure.

EARTHQUAKES AS RANDOM IMPULSE SERIES

Examination of accelerograms of ground motions, responses and response spectra from past earthquakes provides the basis for discussing characteristics of earthquakes. The most notable feature is the complexity and irregularity of most ground motions and the lack of reward in trying to analyse accelerograms for any sort of periodic motion characteristic of either the earthquake or the ground. Cases of "dominant ground periods" are found only when a thick layer of soft material overlies bed rock and similarly in the neighbourhood of massive structures, where a systematic set of reflections of pulses can be set up. The occurrence of such thick layers of soft material in Japan has led to a great concentration of effort on this aspect of the subject. Similar conditions exist in Mexico City.

In the United States, on the other hand, where in one case an accelerograph sited on fill close to a sea wall showed what was considered to be a dominant ground period of about 1·0 second for this particular site, most of the other cases showed complete irregularity. This irregularity in the response spectrum has led to the study of random impulses and their response spectra. The dates of occurrence and intensities of future earthquakes can be treated rationally only by the theory of probability and it is attractive to try to combine these with a study of random impulse earthquakes to provide a combined strength requirement in a form suitable for the structural designer.

A theoretical model of an earthquake may therefore be made to consist of a series of random impulses defined as instantaneous changes of velocity and the fact that this change in velocity takes place in a finite time and may be represented by many different acceleration-time curves is dealt with by a correction factor. The earthquake is once again treated as one dimensional and the randomness is expressed in only one variable; it is immaterial whether the pulses are treated as equal and random in time or as evenly spaced in time and random in magnitude. Housner[2] has considered a series of impulses random in time and has shown that for a large number of "synthetic earthquakes" made up of random impulses the mean value of S_v is the same, no matter what the value of T, i.e., the mean velocity response spectrum is a horizontal straight line. This is a most valuable result, bringing great simplification to the problem of designing against earthquakes, in spite of the refinements and qualifications with which it is necessary to surround it. Thus, it will be noted that the maximum energy imparted to the mass is $\frac{1}{2}mS_v^2$ and that averaging over a large number of synthetic earthquakes, this too is independent of the natural period of the system.

Any single synthetic earthquake made up of random impulses will have a velocity spectrum with random peaks and valleys: S_v will not be independent of the value of T. Any single real earthquake will in the same way show S_v varying irregularly for different values of T. The sorting out of the differences between the random variations of the synthetic earthquake and the irregularities of the real earthquake is likely to be unrewarding, but two points are worthy of note. The first is that velocity spectrum curves of real earthquakes all tend to zero as T tends to zero and this may be accounted for by considering pulses of finite time that are not small compared with very low values of T. The other is that the effect of viscous damping in a building is to even out the irregularities in the velocity spectrum so that the spectrum for $n = 0{\cdot}02$, for example, is very much more regular than the undamped spectrum and any individual spectrum is much closer to the ideal one. Further refinements have been discussed by Housner[2] and Rosenblueth.[4] Rosenblueth discusses the case of a building sited on the sort of geological formation which does have a dominant ground period as a result of systematic reflections at strata boundaries, the random impulses being replaced by a damped chain of pulses. These refinements, however, go rather beyond the range of observational justification and are at present primarily of theoretical interest.

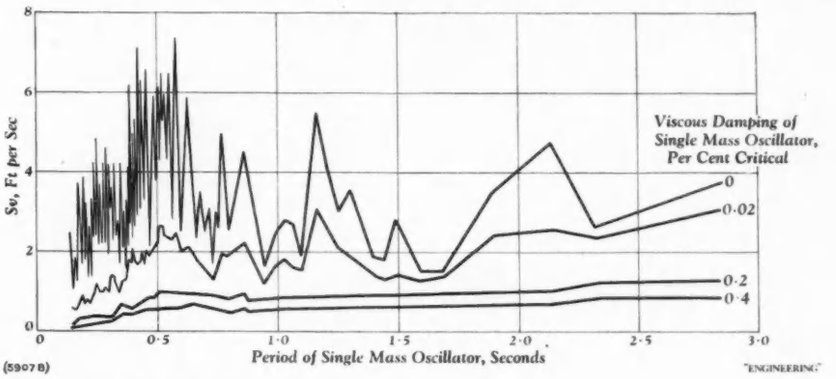


Fig. 2 The velocity-response spectrum for the east-west component of the earthquake at El Centro, Mexico, on 18 May, 1940. It is taken from Reference 9.

While the mean velocity spectrum from a large number of earthquakes tends to a horizontal straight line, the irregularities caused by any single synthetic earthquake indicate that a factor of safety must be applied if such a model is to be used for designing against a future earthquake, and an important refinement discussed in the papers referred to above is a consideration of the dispersion of individual response spectra about the mean.

In the discussion above, the one dimensional earthquake motion has been treated as one of the components of the horizontal motion. The vertical motion is of the same order of magnitude and may be treated by the same means. It is, however, of very much less significance in the behaviour of structures.

RESPONSE OF COMPLEX STRUCTURES

Equation (1) is the equation of motion of a simple elastic spring mass system with viscous damping. It is desirable to extend the investigation to deal with systems of several degrees of freedom and of an infinite number of degrees of freedom and to consider non-linear behaviour of the parts of the structure which have been idealised as springs. Some consideration must also be given to a three-dimensional structure subjected to a three-dimensional ground motion. The simplification is retained that an earthquake is essentially a variable displacement condition applied to one end of a line of linked masses, though the acceleration derived from this displacement is the function normally used in mathematical analysis.

Graphical methods have been developed for these problems but all are extremely laborious and may now be said to be superseded by computers. The solution of one-dimensional elastic problems with viscous damping can be carried out with the help of an analogue computer on the basis of the electrical analogue shown in Fig. 1 with additional circuits for each degree of freedom.

Continuing Construction

Other problems call for the use of a digital computer and the rapid increase in the numbers of these machines perhaps makes them more readily available for use by investigators. Digital computers involve the replacement of continuous functions by steps at finite intervals of the independent variables. This is quite appropriate for synthetic earthquakes of random impulses, but great care must be taken to ensure that when an accelerogram of a real earthquake is used, none of the peaks are missed. A digital computer can deal with non-linear force-displacement relationships as well as with linear elastic structures.

SHEAR DISTRIBUTION IN TALL BUILDINGS

None-the-less the most valuable work now being done using a digital computer idealises the building as a series of masses concentrated at the levels of the floors, each floor being connected by weightless elastic columns and the whole structure subject to viscous damping.

From the acceleration response spectrum described previously, it is possible to determine the maximum force acting on the mass and if a building is treated as approximating to a single-mass structure, this force is also the base shear applied to the structure. A building with several degrees of freedom has several modes of vibration and several natural periods. Each of these modes will to a greater or lesser extent be excited by the earthquake ground motion and may be treated separately as individual simple structures. Each mode will, of course, have its own maximum shear at the base and between each mass. These will not all necessarily occur at the same time. The investigation of the shear distribution in tall buildings subjected to accelerations recorded in real earthquakes is being carried out by Tung and Newmark[5 6] but it cannot be said that a complete and systematic exploration of all the variables has yet been made; the work is still in progress.

The correlation of this theoretical work with observation is of the greatest importance. The vibrations of buildings as a result of wind, explosions and minor earthquakes have been studied but the prime problem of what modes of vibration are excited by a real earthquake cannot be discovered by these means. In this connection, valuable data may be obtained from the behaviour of the " Latino Americana " building in Mexico City. This 44 storey skyscraper was designed in accordance with the results of a theoretical analysis similar to that described above.[7] A strong earthquake in Mexico City on 28 July, 1957, caused damage to many buildings in the city and the recording instruments within the building should give valuable information of its behaviour. A preliminary account has appeared[8] and more detailed accounts are awaited withtinterest.

NON-LINEAR BEHAVIOUR

Investigations into non-linear behaviour have not yet reached a stage to provide a theoretical background for generalised observations. It must be noted that any idealisation of a building that considers only the behaviour of the structural frame and floors, and neglects the behaviour of all the other material in the building is likely to be very unrealistic. Normal buildings such as blocks of flats or offices show a relatively high damping which gradually increases as the amplitude of vibration increases and more and more irreversible, inelastic processes, such as partition and plaster cracking absorbing energy, occur. Welded bare steel items of industrial plant, on the other hand, show very low damping until the yield point of the steel is reached, after which large amounts of energy can be absorbed with relatively small plastic deformations of anchor bolts, bracing ties, etc. Housner[9] has proposed that such structures should be specifically designed for a certain amount of plastic deformation and discusses the quantities of energy involved.

In all the discussion so far, the structure has been treated as resting on a shaking table and subject to a specific displacement condition. In fact, the building is founded on a non-elastic material which undergoes deformation with changes of load. As a result, an earthquake will excite the building to rock back and forth and an additional degree of freedom is introduced. In the majority of cases, this has negligible effect on the stresses in the structure, and on the absorption of energy by the ground. The rocking building acts as a wave generator converting some of the earthquake energy into waves transmitted back into the ground, but this too, has negligible effect on the stresses in the structure in most cases.

BUILDING REGULATIONS

The public authority in a district known to be liable to earthquakes has the duty of trying to preserve the lives of citizens and so of making regulations to ensure that buildings shaken in an earthquake do not endanger life. But it cannot do this with certainty, since it cannot predict the intensity of future earthquakes. It must, however, decide what intensity of future earthquake is likely over a reasonable period.

Depending on the favoured theory of government, it is not necessarily the task of the public authority to keep financial loss by earthquake damage small; this may perhaps be left to insurance companies. But it is undesirable to have to design buildings to comply with two sets of requirements so that building regulations have to be a compromise to cover monetary considerations as well as safety. These considerations will lead the public authority to lay down the stresses to which the building may be subjected by the conditions envisaged. It will allow one factor of safety to cover irregularities of earthquake behaviour and another to cover uncertainties in the determination of stresses. It may be thought that the duties of a public authority end here and to specify further would unduly hinder the development of design. But the effects of earthquakes are so complex and incompletely understood, even after recent advances, that the public authority is compelled to intervene and prescribe certain rules of thumb justified by experience as producing earthquake resistant design.

As the main effect of an earthquake is to apply horizontal forces to parts of a structure proportional to the masses involved, the strength to withstand an earthquake can be assured if the building is designed to carry certain horizontal forces proportional to the masses. Most earthquake codes specify a single basic force coefficient, with a few rules for modifying it where necessary, and the horizontal force so specified is treated as a static force acting on the structure. The single coefficient cannot, of course, be appropriate to all parts of all structures, so that a large factor of safety must be incorporated at correspondingly increased cost. This also has the effect of forcing the designer to choose horizontal rigidity as his guiding principle, though there are cases where to design for flexibility would give greater earthquake strength. In codes dealing with tall buildings, the coefficient specified is sometimes that for base shear and the variation of shear with height is specified.

In an attempt to use recent earthquake research to formulate a more sophisticated building code, the first problem is to correlate the intensity of the earthquake with its response spectrum. The intensity of earthquakes is usually estimated on a descriptive scale and many of the descriptions refer to the effects on buildings. For example, an earthquake of intensity VIII on the modified Mercalli scale is described as corresponding to:

> " Damage slight in specially designed structures; considerable in ordinary buildings, with partial collapse; great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbs persons driving motor cars."

The risks of begging the question are obvious here. Housner[10] has suggested that intensities of past earthquakes should be related to the area under the velocity response spectrum curve. Idealised velocity response spectrum curves may then be specified. It will probably be necessary to specify two safe limiting (i.e. on the low side) values of damping, one for ordinary buildings stressed to the acceptable damage limits and one for bare steel structures within the elastic range. The derivation of base shear may then be made using equation 9. It will be seen that for a constant value of S_v, to which an idealised curve will approximate for the larger values of T, the base shear coefficient is inversely proportional to T, so that designing for flexibility and a corresponding high value of T will not be unreasonably penalised. For a structure approximating closely to a single degree of freedom structure, this procedure has no dangers. Where higher modes are likely to be excited, the regulations must deal with the risks involved. The procedure outlined here follows that recommended in their pioneer work by the Joint Committee of the San Francisco Section of the American Society of Civil Engineers and the Structural Engineers' Association of Northern California.[11]

At various stages in this work, uncertainties exist and there is a temptation to take safe limiting values. If this is done at each stage of the work, the safety factors pile up and the designer is forced into designing for rigidity. It is preferable that mean values should be taken in each case and the probable dispersion or error estimated and that safety should be considered on a probability basis as a separate study. After this study, the safe limiting figures to be specified in the regulations may be chosen.

It would be desirable to include a clause permitting the absorption of energy by controlled plastic deformation of structural elements of a ductile material with a specific yield point.

A set of building regulations on these principles would not unduly hamper the structural designer. It would, however, be very sensitive to the pace of research into the behaviour of buildings in earthquakes and the public authority should be prepared to consider quite drastic revision every five years or so and make arrangements to be able to do this. Arrangements should be made for the waiving of the regulations where a structural designer offers new principles to justify his design and expert opinion should be made available to rule on the soundness of the principles and the adequacy of the design.

STRUCTURAL DESIGN

It is only in rare cases of exceptionally expensive buildings or for the prototypes of completely new types of buildings or plant such, for example, as a nuclear power station, that the cost of a complete dynamic investigation is justified. For the great majority of structures, compliance with the local building regulations may produce a slightly over-designed structure, but the savings from tighter design will be outweighed by the higher design costs. Nonetheless, expenditure on research projects will give a greater understanding of the behaviour of buildings and will lead to building regulations which are as good as possible, a compromise between the conflicting requirements of simplicity and closeness to the reality of a complex phenomenon.

Care in detail design of column, beam and slab connections is essential. Bond length of reinforcing bars must be generous. Solid floors are preferable to hollow tile reinforced concrete floors, for not only are the tiles likely to drop out, but the torsional stiffness of the thin topping may well be inadequate for movements beyond the scope of analysis. Expansion joints common in European practice are not feasible in earthquake areas.

Operation and Maintenance

FREE-PISTON ENGINES AFLOAT

Power units consisting of free-piston gasifiers and exhaust gas turbines offer several advantages for ship's propulsion, among which are a reduction in weight and space for a given power rating, and versatility in arrangement of the various sub-units. Machinery of this type has been fitted to two French coastal vessels and to some naval ships but up to the present no British ocean-going vessel has existed with free-piston/gas turbine engines. This has now been remedied by the building of the ore carrier "Morar." The ship will go into normal commercial operation and will provide data for the further development of propulsion machinery.

Built by Lithgows Limited, Port Glasgow, for Scottish Ore Carriers Limited the Morar is 427 ft long overall, has a deadweight tonnage of about 9,250, and a service speed of 11 knots. Being designed for bulk carriage of ore only, the ship is not equipped with any cargo-handling machinery. Quick and easy operation of hatches, and rapid discharge of water ballast on arrival at the loading port, both important features of a bulk carrier, are well provided for on the Morar.

The propulsion machinery in the ship represents the first step in a series of developments planned by the newly-formed Lithgow associated company, the Lithgow Power Development Company Limited, Eagle Foundry, Greenock. A second ship, of greater power, is on order for a different owner, and it is the new company's intention to investigate other methods of propulsion as well, including nuclear energy. As the Morar is intended for obtaining operational data, the opportunity has been taken to introduce certain other novel features besides the propulsion machinery, and the behaviour of these items in service will also be studied. They include some plastics cold water piping and some Fibreglass piping in the engine room.

Ease of access for loading and unloading are essential features of a bulk carrier, and the Morar has four large hatches, each 30 ft wide and from 47 ft 3 in to 52 ft 6 in long. All the hatches are fitted with Erman's patent rolling hatch covers, supplied by R. Y. Pickering and Company Limited, Wishaw, an associated company of Lithgows Limited. The covers are of steel plate, folded to channel section and coupled together by side links. An electrically-driven winch barrel, extending across the width of the hatch at one end, draws the channel covers along the coaming, and each channel is so dimensioned that it will nest on the preceding one. As the winch barrel rotates, therefore, the hatch cover channels are drawn clear of the hatch and rolled on to the barrel, leaving the entire hatch area clear of obstruction. Nesting takes place in a small space and there is no obstruction of the deck when the hatches are open. When the winch barrel is reversed, it pushes the covers back along the hatch until it is closed. Limit switches prevent overrun. Rubber jointing between the channels and at the sides ensures that the hatch is watertight. A simple arrangement of hinged strips and wedges, similar in principle to those used on an orthodox hatch, secures the cover when at sea.

When the securing gear is free any of the Morar's hatches can be opened or closed under push-button control in about 2 minutes.

The ship is propelled by an exhaust-gas turbine, driving a single screw through reduction gearing, and taking its gas from three free-piston engines. The propulsion machinery is relatively small compared with orthodox diesel engines as used in the Morar's three sister ships, the estimated weight of the complete installation being about 410 tons, against a total of 630 tons for the sister ships. This gives an increase in deadweight of about 200 tons.

Because the ship is an ore carrier it has not been necessary to use to the full the space saving made possible by the use of free-piston/gas turbine engines; the reduction in engine room length could have been ten frame spaces, but it has only been necessary to reduce it by five. Even with the reduced size of engine room accessibility of machinery is very good, and the whole layout is characterised by its spaciousness.

The engines are aft and there is only a short propeller shaft, coupled to a double-reduction, articulated, locked train type gear unit, made by the Fairfield Shipbuilding and Engineering Company Limited, Glasgow, a Lithgows group company. This gear unit gives a speed of 115 r.p.m. to the propeller shaft with an input speed of 5,250 r.p.m. from the exhaust-gas turbine mounted ahead of it. Electrical turning gear is fitted to the gearing, which also incorporates the thrust block.

The turbine is reversible, having six ahead and two reverse stages, the astern turbine being incorporated in the main casing. It was built by Rankin and Blackmore Limited, Greenock, to the design of Power Jets (Research and Development) Limited, and is of double casing construction, the inner shell carrying the fixed blades, while the fabricated outer casing carries all the external attachments and is subject only to exhaust pressure and temperature conditions. The propulsion machinery has a designed shaft horse-power of 2,500 in service.

Free-piston engines and an exhaust-gas turbine propel the ore carrier "Morar," the first British sea-going merchant ship to be so engined.

Immediately ahead of the turbine are three Ruston and Hornsby diesel generators, which provide the power for lighting and auxiliaries throughout the ship. An oil-fired heating boiler is located near the generators. These items are of orthodox design.

It is a feature of the free-piston engines that they are relatively small and can be installed in any convenient position. In the Morar they are mounted immediately above the diesel generators, and connected to the turbine by short runs of piping. There are three gasifiers, of the Pescara type, built by the Free Piston

---

Continuing Construction

While designing for flexibility, particularly by suspending large masses on flexible hangers, is worthy of consideration for industrial plant it brings difficulties in detail design of ordinary buildings where brittle finishing materials such as plaster and glass are used. Partitions and curtain walls must all be designed to accommodate the large deflections implied by a flexible structure. Japanese practice favours the use of reinforced concrete shear walls to obtain maximum rigidity of buildings.

Observation of damage during recent earthquakes has shown that high standards of detailing and workmanship make a significant contribution to the safety of buildings which undergo earthquake shocks.

REFERENCES

[1] Biot, M. A., "Analytical and Experimental Methods in Engineering Seismology." *Proc. Am. Soc. Civil Engineers* (1942).

[2] Housner, G. W., "Characteristics of Strong Motion Earthquakes." *Bull. Seism. Soc. Amer.*, vol. 37 (1947).

[3] Housner, G. W., "Properties of Strong Ground Motion Earthquakes." *Bull. Seism. Soc. Amer.*, vol. 45 (1955).

[4] Rosenblueth, E., "Some Applications of Probability Theory to Aseismic Design." *Proc. World Conf. Earthquake Engineering* (1956).

[5] Tung, T. P., and Newmark, N. M., "Numerical Analysis of Earthquake Response of a Tall Building". *Bull. Seism. Soc. Amer.*, vol. 45 (1955).

[6] Tung, T. P., and Newmark, N. M., "Shears in a Tall Building Subjected to Strong Motion Earthquakes." *Proc. World Conf. Earthquake Engineering* (1956).

[7] Zeevaert, L., and Newmark, N. M., "Aseismic Design of Latino Americana Tower in Mexico City." *Proc. World Conf. Earthquake Engineering* (1956).

[8] "No Damage Occurred to Tallest Building." *Engineering News-Record*, vol. 15 (1957).

[9] Housner, G. W., "Limit Design of Structures to Resist Earthquakes." *Proc. World Conf. Earthquake Engineering* (1956).

[10] Housner, G. W., "Spectrum Intensities of Strong Motion Earthquakes." *Symposium on Earthquake and Blast Effects on Structures* (1952).

[11] Joint Committee, "Lateral Forces of Earthquake and Wind." *Trans. Am. Soc. Civil Engineers*, vol. 117 (1952).

Continuing **Operation and Maintenance**

Engine Company under licence from Alan Muntz and Company Limited. They are of the standard GS34 size, and each is designed to provide 1,230 gas h.p. or about 1,000 equivalent s.h.p.; there is thus an overall reserve of power. The free-piston engine has been described in these columns.*

One novelty in the method of installation is that in the Morar the air supply for the gas generators is ducted in from the ship's funnel, and this, together with careful attention to the question of acoustics, has resulted in a very reasonable noise level in the engine room. It has sometimes been said that free-piston engines are unpleasantly noisy; experience during the trials of the Morar has shown that in the present ship, at least, this is not so. In fact, the engine room noise is no more than would be experienced with orthodox diesel propulsion machinery.

Control of the propulsion machinery is from a central desk and instrument panel designed and made by Rankin and Blackmore Limited, who also undertook responsibility for the installation of the complete machinery. A single handwheel regulates the load on the gasifiers and at the same time controls a proportioning valve which allows gases to enter the ahead or astern turbine. This valve can also direct gas to both sides of the turbine simultaneously, in varying proportions, which allows of fine adjustment when manoeuvring. Preliminary trials have shown the ship to manoeuvre well, and it has been demonstrated that the ship will run at reduced speed with only two gasifiers in operation, or maintain steerage way with only one. Up to the present the fuel consumption, 0·49 lb per s.h.p. per hr, has not been reduced to the figure required, but developments are in hand to achieve the desired result, and a second turbine, incorporating improvements suggested by operational experience, is under construction. At a later date it is intended to install this new turbine in the ship and to use the existing one for test bed research.

* ENGNG. Vol. 181., 1956, p. 371.

ATMOSPHERIC POLLUTION BY SOLID PARTICLES

Measuring Significant Particle Surface Area by Charge Transfer

By D. H. GRINDELL, PH.D., B.SC.

Research Laboratory, the British Thomson-Houston Company Ltd.

WITH the advent of the Clean Air Act in June, 1958, limitation by law of atmospheric contamination became a first positive step towards the attainment of clean air in urban and manufacturing areas. The effectiveness of preventive measures enforced by the act remains to be determined by large-scale measurement both of atmospheric particle and gaseous impurities, and of the smoke or grit content of discharges from industrial chimneys.

Dusts, grits and smokes in the atmosphere constitute a serious threat to the health and well-being of the nation, and are responsible for an appreciable loss in economy, yet, so far, there is no comprehensive solution to the problem of measuring the actual offensiveness of a chimney discharge.

One very serious feature of atmospheric contamination is that, under appropriate meteorological conditions, industrial fog is induced by the finer particles acting as nuclei for condensation. If smoke emission is continued under these circumstances, dispersal of the impurities becomes restricted and a smoke-fog will ensue.

Since those particles which most readily promote fog are comparable in size with, or even smaller than, the wavelength of visible light, and so are virtually transparent, the validity of measurements by optical methods becomes doubtful. Furthermore, the total weight of airborne smokes in a given volume of air cannot be directly related either to fog formation or to the adverse effects upon health; neither is this factor of any great significance in the study of the transport, diffusion and deposition of airborne solids. Thus, although the law assesses smoke density by a visual comparison of its darkness with standard shade cards and the present methods of measuring air pollution are either gravimetric or optical, the relevance of the information provided by these measurements is limited.

For reasons which become apparent when the effects of atmospheric contamination are studied in detail, a comprehensive statement of its nature should include the surface area, number, size distribution, and chemical composition of the particles. For it is these factors, rather than gross weight or opacity, which, together with chimney design, influence the way in which the particles are broadcast, and which determine their fog-forming and toxic consequences.

The effects of pollution may be placed under these general headings:—(*a*) Industrial fog; (*b*) economic loss; and (*c*) pathological consequences.

AIR POLLUTION AND FOG

Fog occurs when moist air near the ground is cooled to a temperature below the dew point by, for example, the loss of heat due to radiation or movement of warm air over cold ground.

Experiment has shown that condensation does not take place unless solid particles or ions are present to act as nuclei upon which the water droplets form.

However, in carefully purified air condensation on negative ion nuclei does not occur until supersaturations of at least 400 per cent are reached and the positive ions do not become active nuclei until supersaturation reaches about 600 per cent. Since condensation in the atmosphere normally occurs at supersaturations of only 1 per cent, the important nuclei cannot be ions. They have been found to be either fine hygroscopic salts originating from sea-spray or the acid products of combustion. These can hold liquid films at relative humidities as low as 50 per cent, and at higher humidities they become droplets of solution which act as very efficient nuclei for further condensation. Moreover, being solutions, they can exist in the liquid state at temperatures below 0° C.

In heavily polluted air there are, as well as those nuclei normally present in the atmosphere which are responsible for natural fog and cloud formation, large numbers of hygroscopic salts and sulphuric acid particles arising from industrial processes and the combustion of coal and other fuels.

While the largest particles are the most efficient as centres of condensation, those with diameters between 0·2 and 2·0 microns, being the more abundant, form the more important group of nuclei.

In industrial areas fog is more likely to occur than in clean air because of the higher concentration of atmospheric nuclei. Moreover, if other conditions remain equal, fog in polluted air tends to have a smaller mean droplet size than that occurring in relatively clean air since droplet growth is restricted by the amount of available water vapour. It follows that in an industrial fog, for the same quantity of suspended water, the total surface area of liquid drops is greater and the visual range less.

In certain weather conditions, a temperature inversion may occur in which atmospheric turbulence is at a minimum and smoke disperses only very slowly. Inversions often remain for a considerable time giving rise to a pall over an industrial area and if fog is also present, the pollution may become occluded in the water particles to create a distressing smoke-fog. As many as 10^6 particles per cc of air have been found in these conditions compared with only a few per cc in country air. A considerable proportion of these droplets are found to be electrically charged, a fact that is believed to influence the persistence of the smoke-fog by reducing the number of collisions between particles and thus decreasing the chances of coalescence and precipitation.

ECONOMIC LOSS

It has been tentatively stated in the report of the Committee on Air Pollution[1] that atmospheric contamination costs the nation about £250 million per year, taking into account only those losses which can be given a monetary value. This estimate includes direct costs such as, among others, the repair and cleaning of buildings, corrosion, laundry, damage to goods, additional lighting, and hospital and medical services. Allowance was made for loss of efficiency, both human due to illness, and agricultural due to adverse effects of pollution upon animals and crops; interference with transport was also considered.

Here, the pollution must be classified as either suspended in the atmosphere or deposited. Loss due to deposited matter clearly depends upon the weight and chemical properties of solids falling over a given area, but the rate of deposition depends upon the physical properties of particles,

the atmospheric conditions and distance from the source of the pollution. The loss due to suspended material depends more upon its particle size and surface area than weight, but also, of course, upon chemical composition.

EFFECTS ON HEALTH

It is certain that air pollution is injurious to health.[1] It causes damage to the respiratory system and promotes bronchitis, pneumonia, influenza, lung cancer, pneumoconiosis and tuberculosis. It can be fatal to the aged and those suffering from some cardio-respiratory complaint, as was evident from the 4,000 or more deaths during the London "smog" of 1952. It obscures daylight, reduces resistance to infection, retards recovery from illness, inhibits growth, and may have serious psychological effects.

One example of the environmental hazards to which some are subjected is silicosis, the causes of which, together with the allied problem of airborne particle deposition in the lungs, have been the subject of considerable research. Recent work has led to the belief that damage to the lung structure is primarily due to the gradual solution of silica in the lung fluids causing areas of fibrosis, and the formation of cavities.

The relevant feature here is the total surface area inhaled, this being the most toxic when the particle diameter of the retained dust lies between 1 and 2 μ; solution is then neither too fast nor too slow to cause a chronic irritation of the lungs.

The filtration efficiency of the respiratory system and the deposition of particles in it depends mainly upon particle size. Those of diameter greater than 10 to 12 μ are trapped in the complex system of nasal hairs and small bones. The majority of particles less than 5μ in size escape this filter, but are retained before they reach the lungs; those between 0·8 and 1·6 μ reach the lungs where they are either absorbed into the blood stream or remain to create a potential danger. About 80 per cent of particles ranging from 0·2 to 0·3 μ are exhaled.

DISPERSION OF SMOKES

It is estimated that of the 200 million tons or so of coal used each year in Great Britain there are emitted to the atmosphere 2 million tons of smoke, 0·8 million tons of grit and dust and 4·4 million tons of sulphur dioxide. Less than a quarter of this coal is consumed in domestic grates, though these account for half the smoke, discharging it, moreover, at a low level.

Chimney design is an important factor in the dispersion of smoke and dust. Generally, the higher the chimney the greater the dispersion of the particles in the upper levels of the air, but if the velocity of the gases at the mouth of the chimney is low, a down-wash of smoke may be caused by eddies on its lee side in windy weather.

The dispersion of smoke is determined even more by the size and mass of the individual particles. This has been recognised by power station authorities; the Electricity Commissioners recommended some time ago that generating station chimneys should not emit more than 0·4 grain of dust per cubic foot of gas discharged, while at the same time specifying that not more than 0·15 grain of this should have a particle diameter greater than 20 microns. However, since flue dust contains very large and light—even hollow—particles, together with smaller ones of greater mass, the importance of free-falling velocity was soon recognised and a later suggestion placed a minimum limit on this quantity, although its measurement presents difficulty.

In a large power station, although the combustion efficiency may be very high and the carbon content of the fly ash correspondingly small, and although dust arrestors may allow only 2 per cent of the ash to enter the atmosphere, the daily quantity of discharged solid impurities can still amount to 10 tons. To the eye, the chimneys may appear to emit only a light haze, and the dusts are widely dispersed in the atmosphere. Nevertheless, installations of this kind constitute a potentially important source of air pollution.

A pamphlet[2] has been prepared by the Department of Scientific and Industrial Research describing methods of measuring air pollution and schemes whereby local authorities and other interested bodies can combine their resources and information to alleviate this national problem.

The quantity of matter deposited over an area is measured by the British Standard Deposit Gauge which collects coarse dusts and grits that settle out of the atmosphere, together with other impurities washed down by rain. Observations must continue for a number of years to enable the results of changes in smoke emission to be separated from those due to weather fluctuations in the analysis of the contents of the gauge. Alternatively, short-time observations may be made by collecting samples in Petri dishes in special conditions of weather.

WEIGHT CONCENTRATION

The weight concentration of atmospheric particles may be determined by drawing a measured amount of air through a white filter paper. The darkness of the resulting stain depends upon the weight of material caught, the particle size, and particle colour, and can be compared with standard stains. The method is useful for comparing smokes but the accuracy of the calibration to which the pamphlet refers, is uncertain since it is based on observations made in London smoke in 1917.

Sampling flue gases to determine the weight of dust and grit emitted to the atmosphere is performed by extracting a known volume of gas and passing it through a filter thimble for a definite period of time. If the thimble is then weighed, the particle concentration may be expressed in terms of grains of solid matter per cubic foot of sampled gas; from this, the number of tons of ash discharged to the atmosphere each year may be estimated if sufficiently representative readings are taken. The difficulty lies in obtaining a true sample, since the dust burden varies over the duct section as well as with the coal and boiler characteristics.

The legal limits of black smoke are defined by the Ringelmann Scale, "dark" smoke being equivalent to or darker than shade 2. This system was devised some 50 years ago for the external observation of chimney smokes and compares the shade of the smoke with standard cards. Each card is printed with a mesh of black lines and when held at a distance from the observer, these appear to merge together producing shades of grey, numbered 1 to 4, according so the thickness of the lines. Number 0 repretents "no smoke" and Number 5 is equivalent to complete opacity. Clearly, the method is not intended to give information about the actual quantity of smoke but only its blackness or offensiveness to the eye; it cannot therefore be used for the white plume of a cement works. Moreover, the observer's judgment may be affected by the brightness and uniformity of the sky, the wind velocity and chimney diameter, so personal experience is an important factor in assessing the result.

A usual method of determining smoke density in a chimney consists in measuring photo-electrically the extinction of a light beam projected across the duct. The meter is calibrated in terms of the Ringelmann Scale and some instruments have automatic means for preventing sooting of the optical lenses, or allowing for ageing of the projector lamp. The attenuation of the beam depends upon its length, particle concentration, particle opacity and size distribution relative to the wavelength of light.

Several methods exist for determining the surface area of a given weight of precipitated dust but most possess the drawback that the degree of particle aggregation of the sample may differ from that of the original suspension. The permeability method in which air is passed through a sample of collected dust to measure the pressure difference across the bed is useful in finding the specific surface. Knowing this, the weight concentration can be converted to surface area or vice versa.

The number concentration of a dust cloud can be estimated by a microscopic count of the sample, either with the particles still airborne or after collection upon a slide. Other apparatus has been described in an excellent book by Green and Lane.[3]

It has been seen that for the study of industrial fogs, knowledge is required of the number, total surface area and chemical composition of airborne particles, the important size range being from about 0·2 to 2·0 microns diameter. Again, the effects upon health are determined by the number, surface area and chemical properties of the particles and the most toxic are of the order of 1 micron in size. For deposited matter, number and volume are important, while opacity is dependent upon number and surface area of particles (provided their size is comparable with or greater than the wavelength of the illumination).

Apparatus is therefore required which will respond to particles of diameter down to 0·1 micron and which will measure either the number or the total surface area of particles discharged in a given time. Preferably, such equipment should monitor the smoke continuously and be suitable for installation in a chimney duct. None of the methods so far discussed is entirely suitable; those based on optical principles are less sensitive when applied to the very fine dusts so serious for toxic and fog-inducing properties.

ELECTROSTATIC SAMPLER

For these reasons, research is in progress to explore an electrostatic method of measuring the total surface area of particles in a sample of polluted gas (either as a quantity or a rate).

The technique[4] being considered employs apparatus very similar to a two-stage electrostatic precipitator, the basic principles of which have been well described by Lowe and Lucas.[5] A continuous sample of flue gas or polluted air is passed first through a section of the instrument where each particle is charged by high-voltage corona, such as from a sharply pointed needle, and afterwards to a measuring section. Here, the charged dust or smoke is impelled by an electric field to a collecting electrode where it deposits its charge. This transfer of charge constitutes a current flowing from the collector to an amplifier, the output of which feeds a recorder. Now it is a property of particles charged in this way that each shall carry an amount of charge proportional—roughly—to its area, so the charge current, which is recorded, is proportional to the surface area of the solids passing through the apparatus in unit time. The equipment can be extremely sensitive and detects particles ranging from fine cigarette smokes to the fly ash leaving the main dust arresting plant of a large industrial pulverised-fuel-fired boiler installation.

It is hoped that this and other new techniques will alleviate the difficulties of measuring smoke emission and so contribute towards the greater problem of attaining cleaner air in industrial areas.

Acknowledgments.—The author wishes to acknowledge the assistance of his colleagues in the Research Laboratory of the British Thomson-Houston Company Limited at Rugby, and is particularly grateful to Dr. K. J. R. Wilkinson for his advice in the preparation of this article.

REFERENCES

[1] *Report* of the Committee on Air Pollution; HMSO, Nov. 1954.

[2] *Measurement of Air Pollution*, DSIR report; HMSO, 1957.

[3] Green, H. L., and Lane, W. R., *Particulate Clouds, Dusts, Smokes and Mists*; SPON, London, 1957.

[4] Grindell, D. H., *Experiments in Smoke Density Measurement, Particle Ionisation and Precipitation*, London Universty Thesis, 1957.

[5] Lowe, H. J., and Lucas, D. H., "The Physics of Electrostatic Precipitation," *Brit. Journal of App. Phys.*, supplement 2, pp 540-547, 1953.

Production

MEASURING SURFACE FINISH

The "Diavite Microtester" is particularly suitable for surface measurement in the production shops, and has an accuracy which also fits it for laboratory use. It is made in Switzerland by H. Hediger, Winterthur and marketed in Great Britain by Payne Products International Limited, Lawrence Estate, Green Lane, Hounslow, Middlesex.

The instrument is equipped with an 8 mm (0·315 m) diameter pick-up, with a diamond stylus which is moved hydraulically across the surface to be measured. A flexible coupling

connects the pick-up to the indicating cabinet, and vertical movements of the stylus relative to skid in which it is held are converted into electrical impulses and pass through an amplifier to an electrical indicator. The indicator shows, in micro-inches, the arithmetical average value of the profile deviations from the mean surface, or centre-line average.

Three interchangeable measuring tracers are available having ranges of 0 to 10, of 0 to 300, and of over 300 micro-in, respectively; the 0 to 300 tracer being supplied as the standard. This tracer will measure flat and curved, concave and convex surfaces, with a minimum radius of approximately 4 mm (0·16 in). Measurement of the maximum depth of profile is also possible.

AUTOMATION IN TYRE MANUFACTURE

Better tyre making has been obtained at Fort Dunlop by installing electronic machinery, operated on a time-temperature basis, to control the mastication of crude rubber and the subsequent mixing of the various ingredients that go to make up the tyres.

Both operations are carried out in Banbury mixers. For mastication, the rubber is manually loaded, the machine button-started and the rubber automatically discharged either when a predetermined temperature is reached or after a fixed time. For mixing, both time and temperature requirements have to be satisfied before discharge. Instrument panels in the control room, each with emergency switches, preset timing mechanism, clocks and visual temperature recorders, ensure control of the mixers. The skilled supervision required has been reduced and faulty mixing nearly eliminated.

Engineering at Home

HEAT PUMPS FOR THE HOME

A Question Answered

In recent years there has been considerable interest in the possibility of using heat-exchange pumps for the central heating of houses. These pumps, which are virtually reversed refrigerators, work on the following lines. Cold air drawn from the atmosphere is expanded, thereby lowering its temperature. Heat passes from the ambient air, or possibly from some other heat source such as a river, into the colder expanded air by natural conduction, so raising its temperature again. Compression of the air back to atmospheric pressure further raises its temperature, until it is considerably warmer than the surroundings. This warmer air can then be used directly or indirectly for room heating.

Although heat-exchange pumps appear to be a highly efficient means of obtaining central heating, they have rarely been used in private homes in this country. In the light of this fact a question was recently put to the Building Research Station of the Department of Scientific and Industrial Research: "Are heat pumps out of the question for central heating in houses?" Their reply was as follows.

The value of heat pumps is basically a matter of economics, depending on whether suitable pumps can be made at a low enough price. No British models for full house heating are available at present but some manufacturers are working to develop suitable units. The advantage of the heat pump over direct fuel-burning apparatus is that it delivers heat (via a warm air or hot-water system) well in excess of the energy it consumes, the excess being obtained by cooling some such source as the outside air. This gain depends partly on the operating temperature of the heating system, and a low-temperature system is the most advantageous. For that reason warm air or floor panels would be used rather than the conventional radiator system. One might expect to obtain three or so units of heat for each unit consumed, that means electric heating at about one third of the normal running cost.

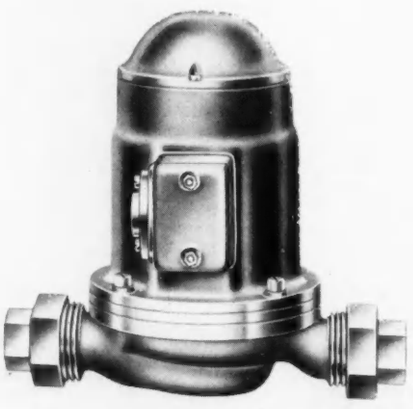
But such a machine, which works on the same principle as the refrigerator, is much more expensive than, say, a normal electric heater of the same capacity. Heat pumps have been used for house heating in America but there the circuit can be reversed to provide necessary summer cooling and the cost of the unit can largely be set against this cooling requirement; this same consideration applies to the small units available here for domestic water heating which provides cooling of the larder.

In this country and further north a heat pump for house heating would normally have to justify itself economically as a heater only, although it could be arranged to provide domestic refrigeration as well. Detailed comparisons are not possible but the running cost quoted is roughly of the same order as that of a solid fuel or oil-fired burner.

It follows that, to be economically attractive, the cost of the heat pump should be comparable with that of the items it replaces, boiler, flue, and fuel store, and possibly part of the cost of a refrigerator.

CENTRAL HEATING CIRCULATOR

Pump for Small Bore Systems



To circulate the water in small-bore central-heating systems, the Saunders Valve Company have introduced a compact water-lubricated pump.

A recent contribution to the simplification of central heating, to the stage when it becomes an economic proposition for the smaller home, is made by the introduction of a new circulating pump for small bore systems. Hot water circulation through small-bore copper piping, which can be quite unobstrusively arranged around wainscot and door frames to the radiator points, is effectively maintained by these compact, glandless units.

Made by the Saunders Valve Company Limited, the "Safrax" circulator will fit piping at any angle, provided the motor is always arranged in a horizontal position. The sleeve bearings are water lubricated, thus eliminating any need for lubrication during service. Provision is made for checking rotation at installation, and the same fitting, incorporated in the nose of the unit, can be used to turn the unit to ensure free running after prolonged inoperation. The motor stator can readily be removed for inspection without disturbing the pipeline or draining the system. The 1/25 h.p. motor consumes 80 watts, running at 1,350 r.p.m. from a 240 volt a.c. supply, and incorporates a suppressor to prevent interference with radio and television reception.

ENGINEERING

Published every Friday by ENGINEERING LTD. at 36 Bedford Street, London, W.C.2.
Telephone: Temple Bar 3663.
Telegrams: Engineering Lesquare London.

CHAIRMAN: J. A. Dixon, M.A., A.M.I.Mech.E.
EDITOR: F. B. Roberts, M.B.E., M.I.Mech.E., A.M.I.Loco.E.
DEPUTY EDITORS: D. Fisher, Ph.D., B.Sc., A.M.I.C.E., A.M.I.Mech.E.; E. P. Ward, M.A., A.M.I.Mech.E.
ASSISTANT EDITORS: J. E. Dodsworth; W. K. V. Gale, M.I.S.I.; J. T. Godfrey; M. Neal, B.Sc., D.I.C., A.F.R.Ae.S.; A. A. H. Scott, B.Sc., A.M.I.Mech.E.
SUBSCRIPTION MANAGER: G. A. Roberts.
ADVERTISEMENT MANAGER: G. H. Dixon.

Annual subscription rates: Inland and abroad £5 10*s* (Canada, £5 5*s*). Three months, 27*s* 6*d* all countries. Single copies, 2*s* 7*d* post free.

Engineering Information Service: Assistance is available from Engineering Information Service in obtaining information, and in locating sources of information, both technical and commercial. EIS deals, for example with names of makers and suppliers of plant and equipment, technical data on design, markets for engineering products, and compilation of references to information on specific topics. Inquiries should be addressed to Engineering Information Service at the address given in the left-hand column.